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> "Fossil records tell us how long a species can survive"
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> **Mass extinction, page 26**

Meet the team…

Nikole
Production Editor
Ghost towns aren't haunted, but they are incredibly eerie. Discover the unsettling settlements left behind on page 42.

Scott
Staff Writer
From pirouetting peacock spiders to egg-laying echidnas, meet some of Australia's weird and wonderful animals on page 36.

Baljeet
Research Editor
NASA successfully landed its latest rover, Perseverance, on the Red Planet in February. Explore the rover and its goals on page 64.

Duncan
Senior Art Editor
Advancing technology enriches our lives in many ways, including when it comes to our kitchens. Find out how on page 50.

Ailsa
Staff Writer
What causes food to spoil? Meet the culprits and learn some tricks to keep your kitchen contents fresh for longer on page 74.

Stevns Klint, shown in the image above, is an 11-mile stretch of cliff in Denmark that's rich in fossils. It's a testimony to life on Earth in the years after the Chixulub impact that wiped out the dinosaurs 66 million years ago. Though it's extremely unlikely that another apocalyptic meteorite strike will happen any time soon, we're in the midst of a catastrophic mass extinction of our own making. In this issue of **How It Works,** we explore the 'Big Five' extinctions of the past, what caused them and how life prevailed. Can we turn back the tide and make our planet healthy again? Certainly we can – and it all starts with little steps that you can make.

Enjoy the issue!

Ben Editor

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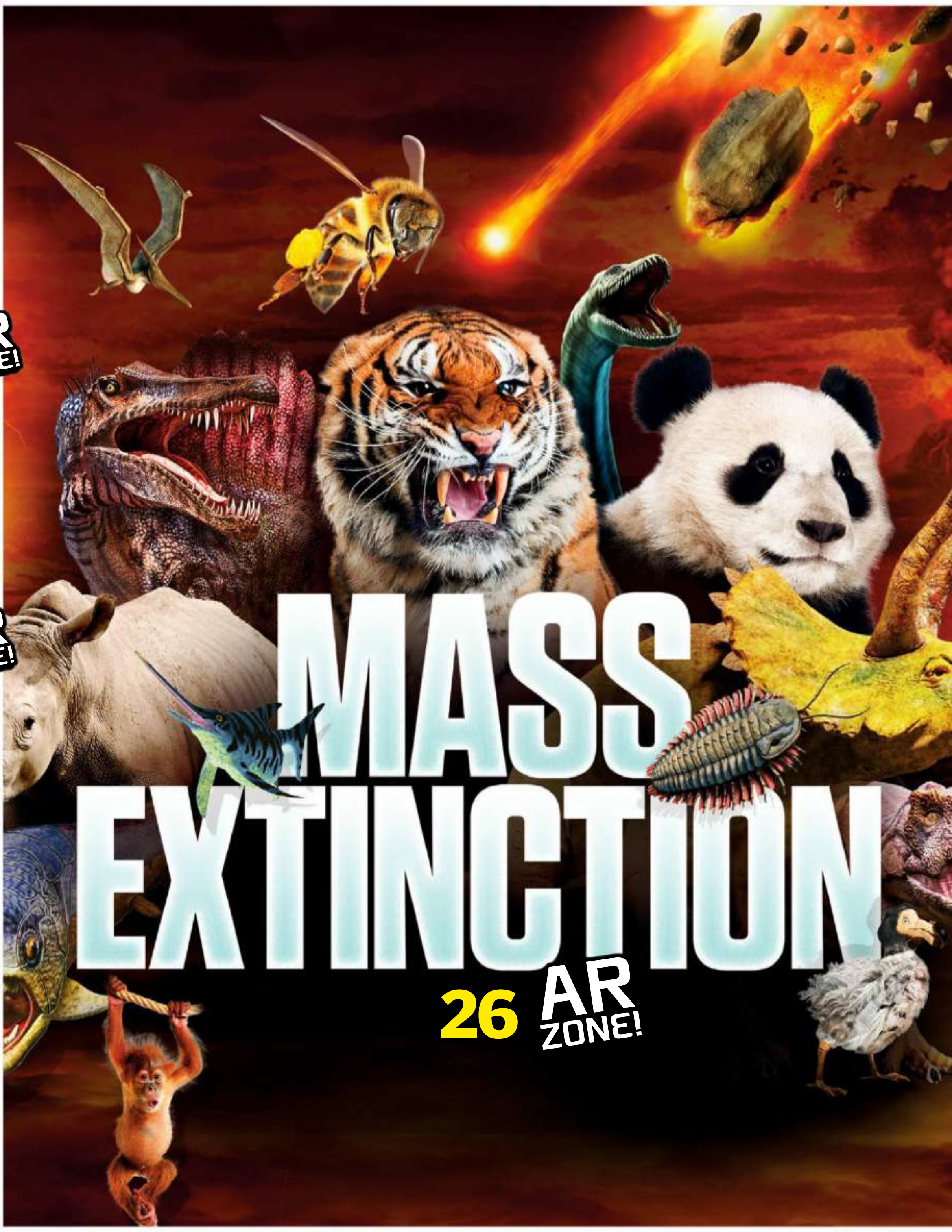
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MEET THIS ISSUE'S EXPERTS…

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

Mike Jennings
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

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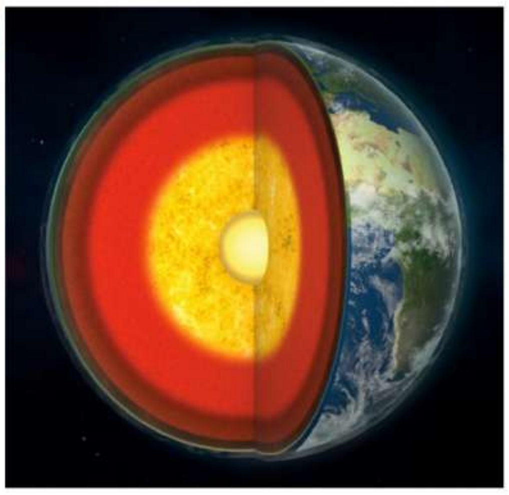

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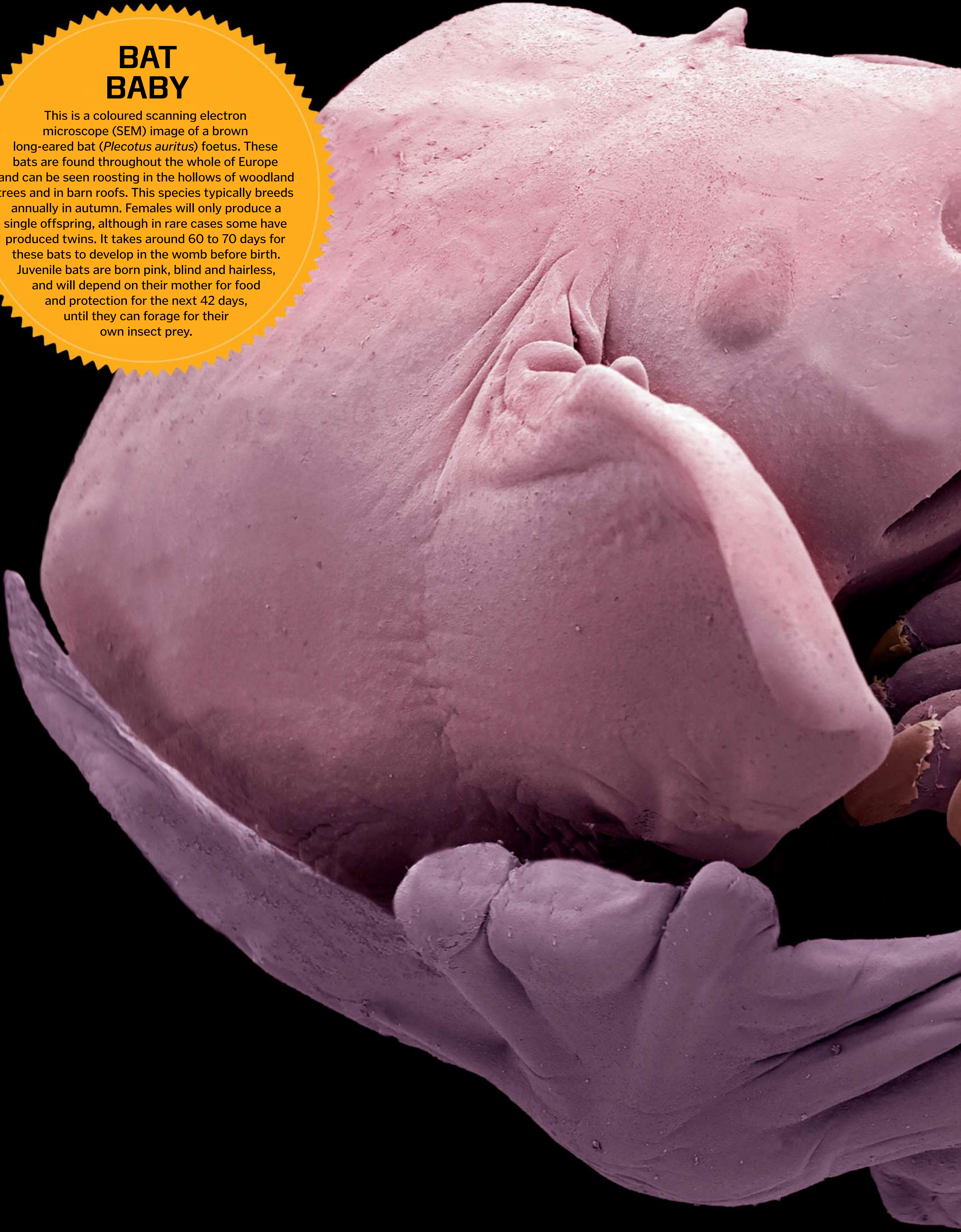

BAT BABY

This is a coloured scanning electron microscope (SEM) image of a brown long-eared bat (*Plecotus auritus*) foetus. These bats are found throughout the whole of Europe and can be seen roosting in the hollows of woodland trees and in barn roofs. This species typically breeds annually in autumn. Females will only produce a single offspring, although in rare cases some have produced twins. It takes around 60 to 70 days for these bats to develop in the womb before birth. Juvenile bats are born pink, blind and hairless, and will depend on their mother for food and protection for the next 42 days, until they can forage for their own insect prey.

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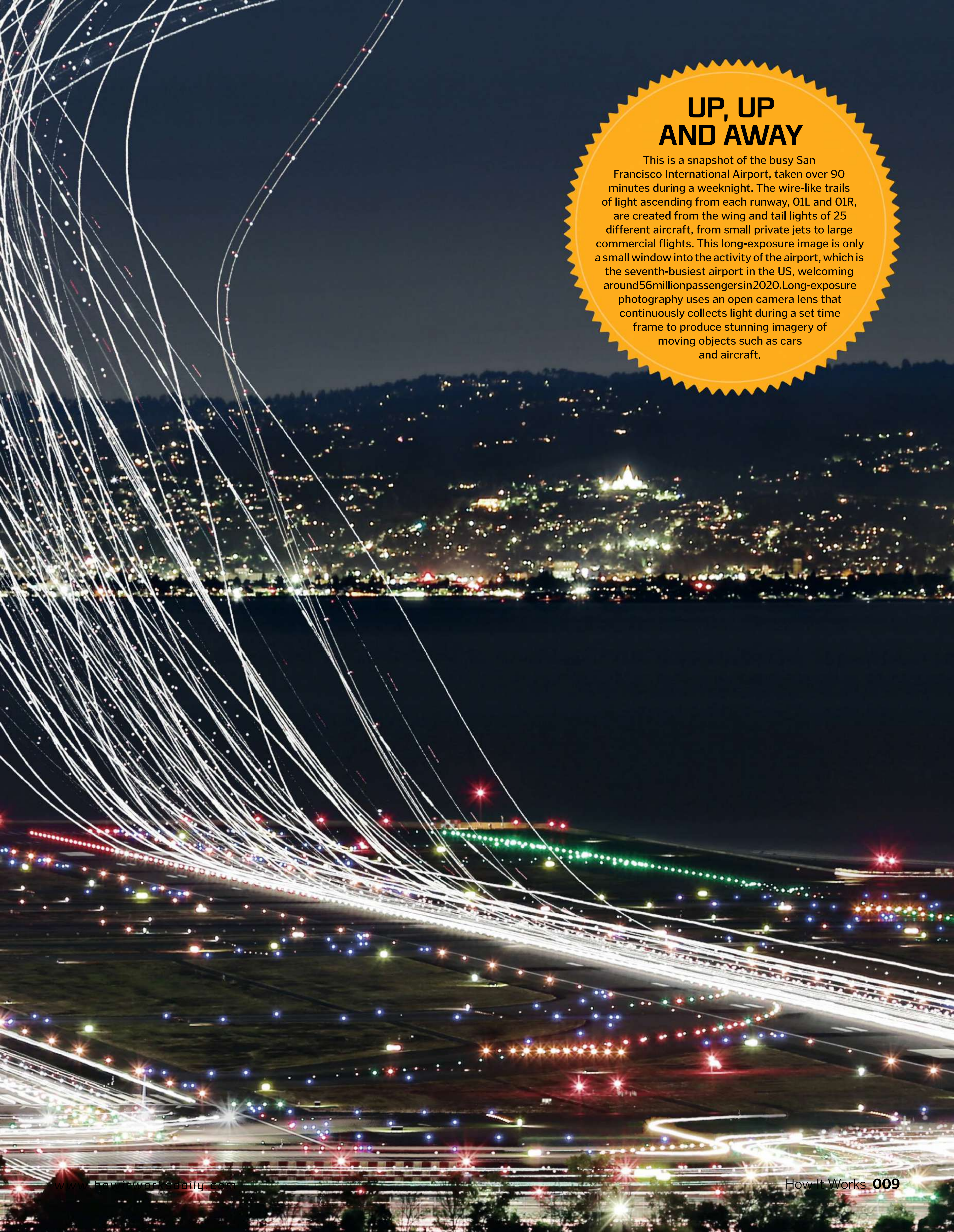
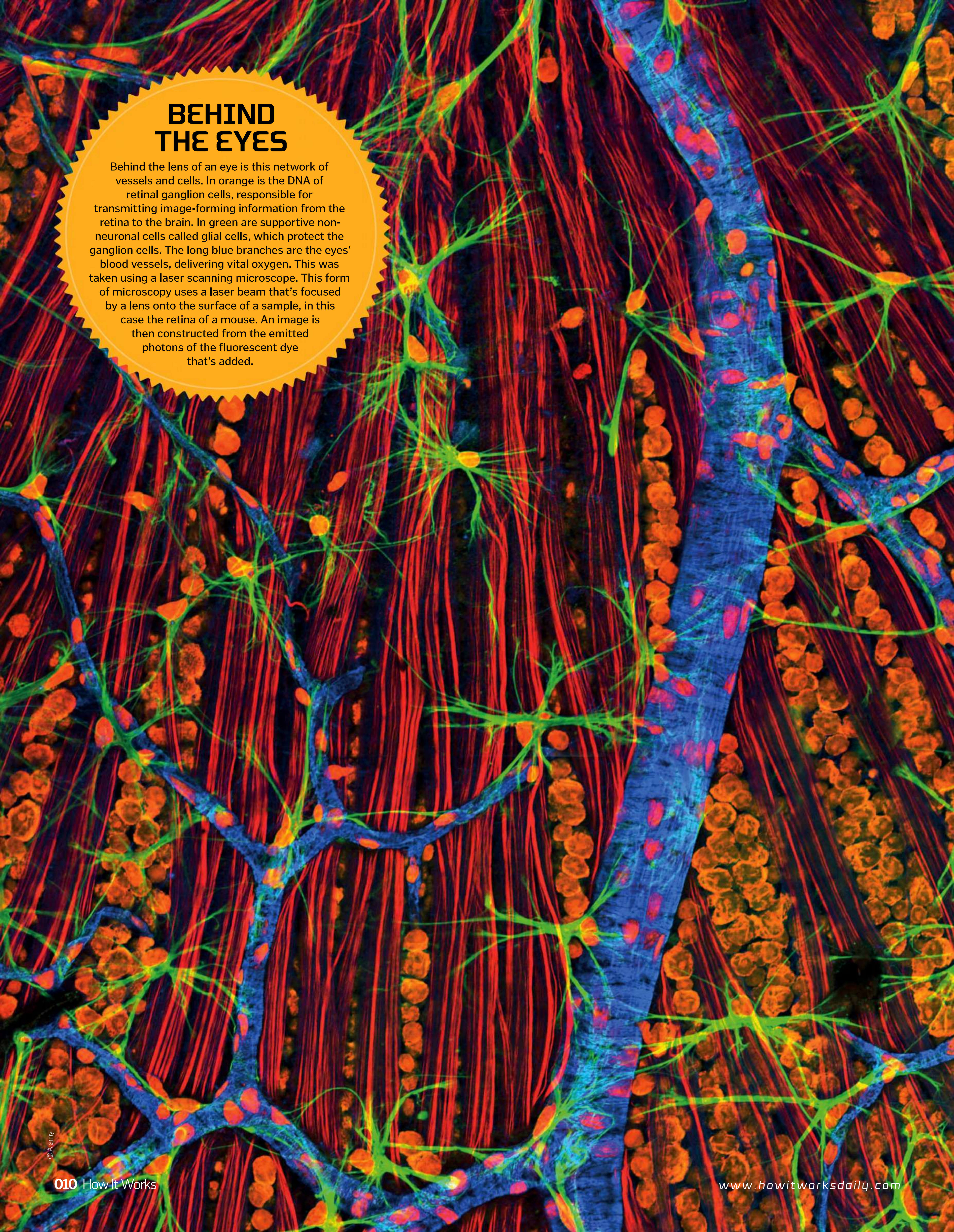


UP, UP AND AWAY

This is a snapshot of the busy San Francisco International Airport, taken over 90 minutes during a weeknight. The wire-like trails of light ascending from each runway, 01L and 01R, are created from the wing and tail lights of 25 different aircraft, from small private jets to large commercial flights. This long-exposure image is only a small window into the activity of the airport, which is the seventh-busiest airport in the US, welcoming around 56 million passengers in 2020. Long-exposure photography uses an open camera lens that continuously collects light during a set time frame to produce stunning imagery of moving objects such as cars and aircraft.



BEHIND THE EYES

Behind the lens of an eye is this network of vessels and cells. In orange is the DNA of retinal ganglion cells, responsible for transmitting image-forming information from the retina to the brain. In green are supportive non-neuronal cells called glial cells, which protect the ganglion cells. The long blue branches are the eyes' blood vessels, delivering vital oxygen. This was taken using a laser scanning microscope. This form of microscopy uses a laser beam that's focused by a lens onto the surface of a sample, in this case the retina of a mouse. An image is then constructed from the emitted photons of the fluorescent dye that's added.

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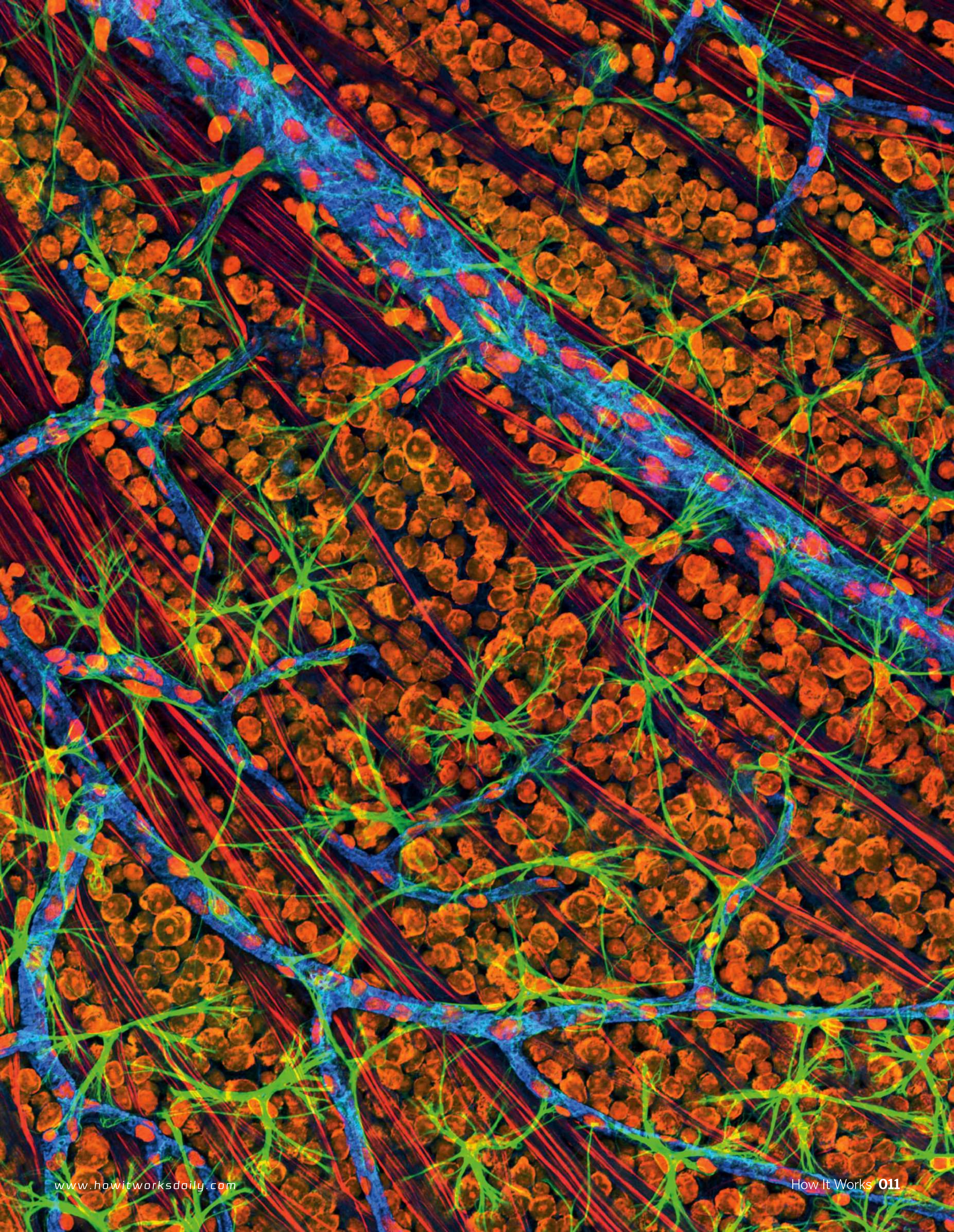

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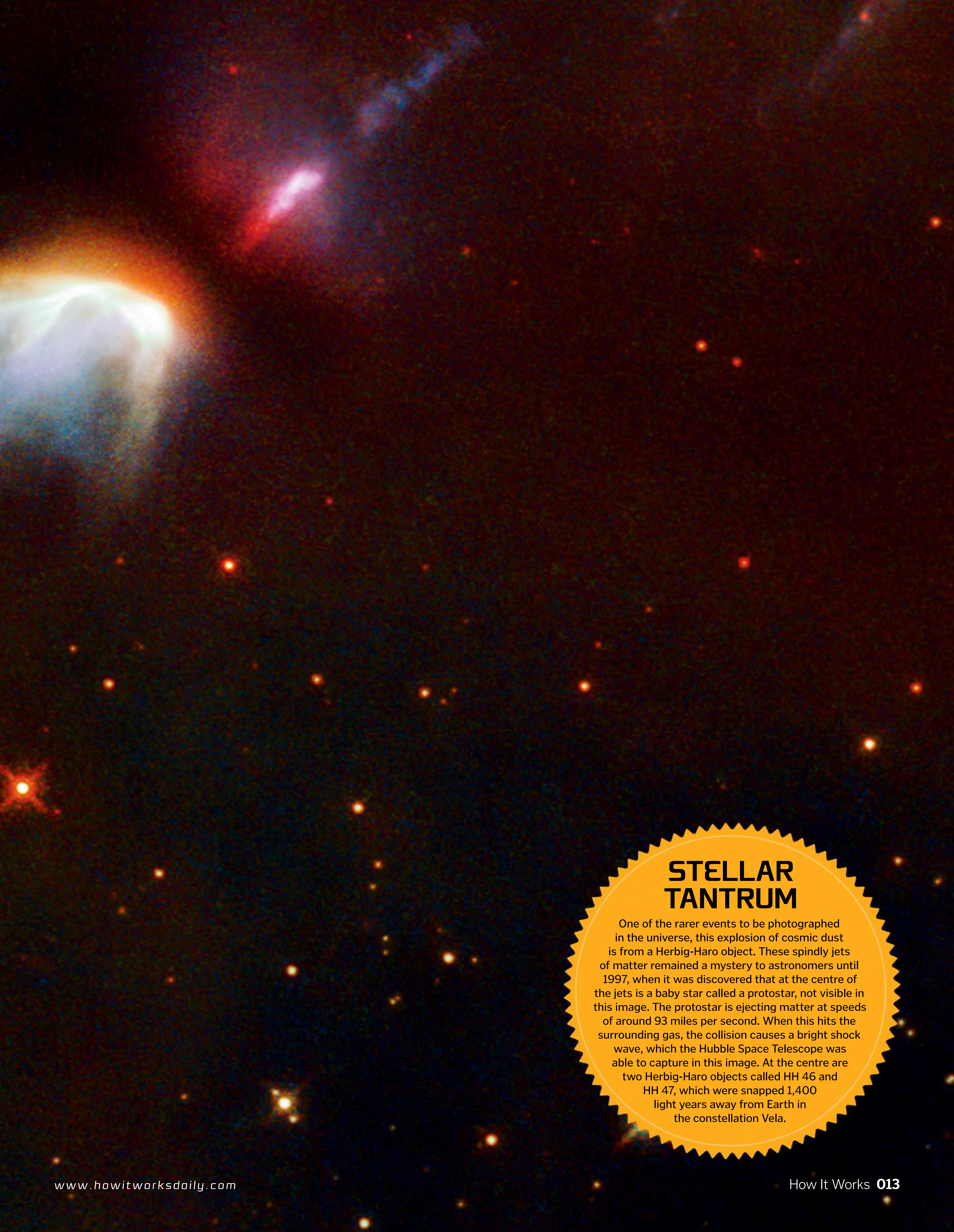

STELLAR TANTRUM

One of the rarer events to be photographed in the universe, this explosion of cosmic dust is from a Herbig-Haro object. These spindly jets of matter remained a mystery to astronomers until 1997, when it was discovered that at the centre of the jets is a baby star called a protostar, not visible in this image. The protostar is ejecting matter at speeds of around 93 miles per second. When this hits the surrounding gas, the collision causes a bright shock wave, which the Hubble Space Telescope was able to capture in this image. At the centre are two Herbig-Haro objects called HH 46 and HH 47, which were snapped 1,400 light years away from Earth in the constellation Vela.

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SPACE

Supermassive black hole speeds through space

Words by **Ben Turner**

A supermassive black hole is racing across the universe at 110,000 miles per hour, and the astronomers who spotted it don't know why. The fast-moving black hole, which is roughly 3 million times heavier than our Sun, is zipping through the centre of the galaxy J0437+2456, about 230 million light years away.

Scientists have long theorised that black holes could move, but such movement is rare because their giant mass requires an equally enormous force to get them going. "We don't expect the majority of supermassive black holes to be moving; they're usually content to just sit around," said Dominic Pesce, an astronomer at the Harvard-Smithsonian Center for Astrophysics.

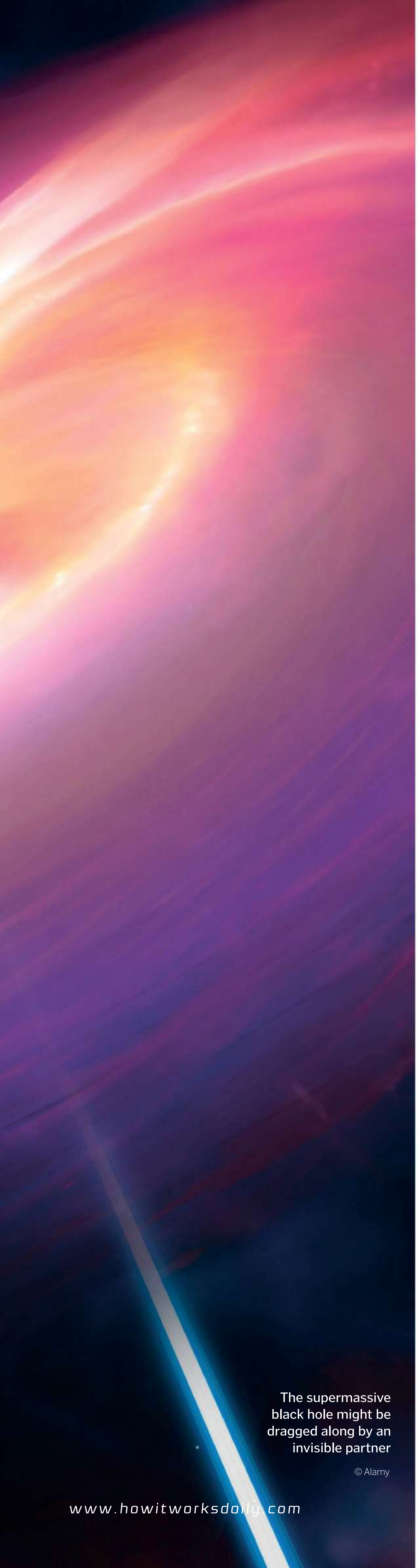
To begin their search for this infrequent cosmic occurrence, the researchers compared the velocities of ten supermassive black holes with the galaxies they formed the centre of, focusing on the black holes with water inside their accretion discs, the spiral-shaped collections of cosmic material in orbit around the black holes.

Why water? As water orbits a black hole, it collides with other material, and the electrons surrounding the hydrogen and oxygen atoms that make up water molecules get excited to higher energy levels. When these electrons return to their ground state, they emit a beam of laser-like microwave radiation called a maser.

By taking advantage of a cosmic phenomenon known as redshift, in which objects moving away have their light stretched to longer wavelengths, the astronomers were able to observe the extent to which the maser light from the accretion disc was shifted away from its known frequency when stationary, thereby gauging the speed of the moving black hole.

They took more observations from various telescopes and combined them all together using a technique called very-long-baseline interferometry; with this technique the researchers could combine the images from several telescopes to effectively act like an image captured by a very big telescope, about the size of the distance between them. In that way the scientists could precisely measure the velocity of the black holes it had originated from.

Of the ten black holes they measured, nine were at rest, and one was on the move. Though 110,000 miles per hour is pretty fast, it's not the fastest supermassive black hole. In 2017 scientists clocked a supermassive black hole hurtling through space at 5 million miles per hour. The researchers don't know what could have made such a heavy object move at such a high speed, but they came up with some possibilities. "We may be observing the aftermath of two supermassive black holes merging," said Jim Condon, a radio astronomer at the National Radio Astronomy Observatory. "The result of such a merger can cause the newborn black hole to recoil, and we may be watching it in the act of recoiling or as it settles down again."



The supermassive black hole might be dragged along by an invisible partner

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Meerkats at a zoo in Italy during a nationwide lockdown to control the spread of COVID-19

ANIMALS

Meerkats happy to see zoo visitors return

Words by **Patrick Pester**

When humans flooded the zoo in South Africa after months of lockdown, the African penguins couldn't have cared less about it. Meanwhile, the bubbly slender-tailed meerkats at a zoo in the UK seemed uplifted by their bipedal visitors.

Researchers studied the behaviour of the animals before and after zoos reopened in the UK and South Africa to learn more about how lockdown affected them. "We can't say what the animals were feeling, but the positive behaviours that we observed – such as positive social interactions with each other and positive human-animal interactions – suggest the return of visitors was a positive and engaging experience for the meerkats," said Ellen Williams, a lecturer in animal behaviour and welfare at Harper Adams University.

Zookeepers began reporting that animals were suffering without the company of visitors. Animals like meerkats were "missing their human friends" in New Zealand zoos, *The Guardian* reported in April 2020, and staff at the Singapore Zoo were taking their African penguins for walks in May to help keep them stimulated without visitors.

These anecdotes led Williams and her colleagues to wonder how the animals were faring during lockdown. "Obviously zoos are not usually closed for long periods of time, and so this study offered us a unique opportunity to understand more about how the meerkats and African penguins were behaving when there were no visitors," Williams said.

Meerkat keepers at Knowsley Safari Park, Twycross Zoo and Plantasia, all in the UK, and penguin keepers at uShaka Sea World in South Africa monitored their animals during five-minute windows and recorded behaviours for the researchers to study. They noted the behaviours the animals were performing, such as foraging for food, and where the animals were positioned in the enclosure.

The meerkats appeared to react well to visitors returning by interacting positively with each other more often, with behaviours such as playing and grooming. They were, however, also more alert once visitors returned, and they spent longer in the parts of their enclosure farthest from visitor viewing areas compared with during lockdown.

The penguins behaved the same regardless of whether there were visitors at their zoo or not, suggesting they didn't care much either way. The research was designed as a pilot study, and the authors advocate for more research over a longer period to better understand the effect that zoo visitors have on the animals.

PLANET EARTH

Antarctic sea creatures uncovered

Words by **Brandon Specktor**

On 26 February 2021, an iceberg large enough to hold New York City nearly two times over cracked off the Antarctic ice sheet and began drifting slowly through the Weddell Sea. Now researchers have gotten a rare glimpse at the marine life living deep below the ice, finally exposed after five decades of ice cover.

Cruising through the narrow gap between the newly liberated iceberg, named A-74, and the Brunt Ice Shelf in northern Antarctica, the German research vessel Polarstern took hours of footage and thousands of photos of the reclusive creatures living 18 miles below the surface. The researchers discovered a bustling community of molluscs, filter feeders, sea stars, sea cucumbers and at least five species of fish and two octopus species.

"The first images from the seafloor reveal an amazing level of biodiversity in a region that was covered by thick ice for decades," said researchers with the Alfred Wegener Institute for Polar and Marine Research (AWI) in Bremerhaven, Germany, which is in charge of the Polarstern mission.

It's not unusual to find marine life thriving near the Antarctic seafloor. Hundreds of marine species live in the frigid waters – sometimes in truly unexpected places. On 15 February, researchers announced the discovery of a colony of sea sponges and other stationary filter feeders clinging to a rock 900 metres below the Filchner-Ronne Ice Shelf, which lies near the Antarctic Peninsula.

That discovery, like the Polarstern's new survey of the Weddell seafloor, threw researchers for a bit of a loop, mainly due to the presence of stationary filter feeders. These animals, which include corals and sponges, perch in place and wait for nutrients to come to them, usually in the form of phytoplankton, a type of microscopic marine algae.

Phytoplankton rely on sunshine for photosynthesis and tend to float in the upper part of the ocean, where the water gets the most sunlight. Finding communities of phytoplankton-gobbling sea creatures living in the darkness deep below the Antarctic ice is counter-intuitive to say the least.

Somehow, nutrients, either in the form of phytoplankton or organic particles flushed to sea with the ice above, are being dragged thousands of metres below the ice shelves of Antarctica to feed the bottom-dwelling creatures there. To learn more about the region's ecosystem, the research team gathered some sediment samples from the seafloor, which will help reveal the water's nutrient content.

The team also stationed research buoys in the area to gather data about the water's temperature and salinity, as well as ocean current speeds in the Weddell Sea. This data will help scientists build more accurate climate models for the region. Antarctica is one of the fastest warming parts of the planet and is at risk of losing most of its ice permanently if greenhouse gas emissions aren't curbed this century.

> "Researchers have gotten a rare glimpse at the marine life"

Sea anemones and filter feeders cling to the rocks hundreds of metres below the Brunt Ice Shelf in Antarctica, where a gargantuan iceberg just broke free

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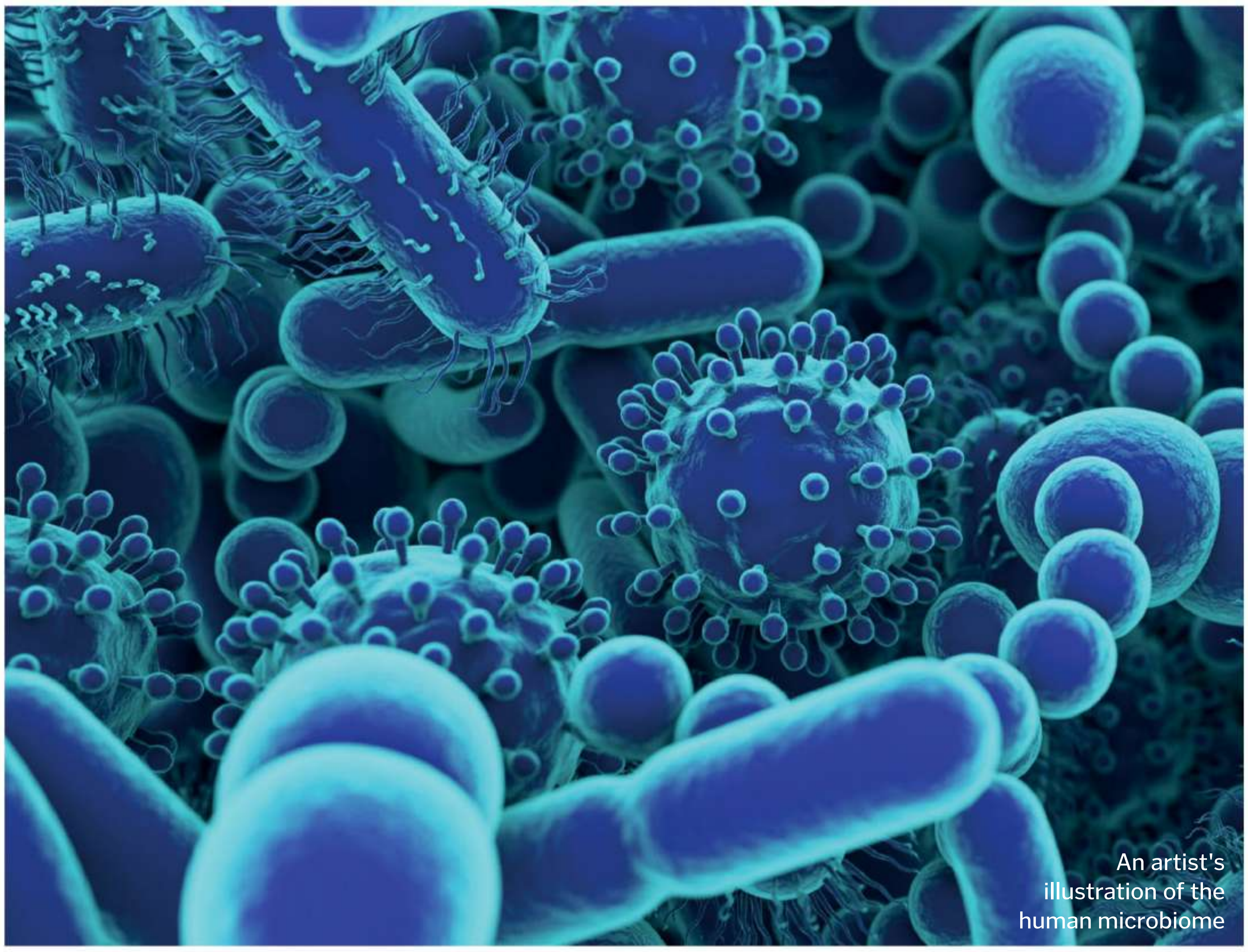


An artist's illustration of the human microbiome

© Getty

HEALTH

70,000 viruses found in the human gut

Words by **Yasemin Saplakoglu**

Scientists have identified more than 70,000 previously unknown viruses that live in the human gut and infect the bacteria that live there, but how they impact our bodies is a mystery. The gut microbiome, or the community of microbes that we carry around in our digestive system, plays an important role in food digestion and regulating the immune system. But many studies have also linked imbalances in gut microbes to conditions including liver disease, obesity and allergies.

Yet shockingly little is known about it. Although the microbiome includes a variety of microorganisms, including bacteria and viruses, previous studies have focused mainly on gut bacteria because they are easier to detect.

A group of researchers has used a method called metagenomics to identify the viruses. This method involves analysing all of the genetic material from a community of microbes together and then mapping the individual sequences found to specific species. They analysed more than 28,000 gut microbiome samples taken from 28 countries.

This process revealed complete genomes for more than 142,000 species of viruses living in the human gut. A single person, however, carries only a fraction of these species. Though many types of viruses live in the gut, they focused on viruses that can infect bacteria called 'bacteriophages', or 'phages' for short.

The researchers limited their scope to bacteriophages because "we are still figuring out their role in human health," said Luis Camarillo-Guerrero, a recent PhD graduate from the Wellcome Sanger Institute. "It's probably safe to say that the vast majority of them are not harmful to us and are simply an integral component of our body microbiota." Phages may play a central role in the gut microbiome, for instance, by providing their bacterial hosts with advantageous traits and influencing how those bacteria evolve.

"As bacterial communities are a critical component of our gut, it's not difficult to imagine that phages could be paying a key role in maintaining a healthy equilibrium in our intestine," said Camarillo-Guerrero. However, there are known cases when phages have contributed to disease. For example, both diphtheria, a serious bacterial infection, and botulism, a serious illness that attacks the body's nerves, are caused by toxins that are encoded by phage genes.

HISTORY

Ancient Greek helmet found in Israel

Words by **Owen Jarus**

A well-preserved ancient Greek helmet likely worn by a soldier during a war with the Persians has been found in the Port of Haifa in Israel. The 2,500-year-old helmet was found by a Dutch ship in 2007 and was turned over to the Israel Antiquities Authority (IAA) marine unit.

"The helmet is a Corinthian type, named after the city of Corinth in Greece where it was first developed and produced in the 6th century BCE," the archaeologists stated, noting that the helmet became popular and was used throughout the Mediterranean.

"The helmet was expertly fabricated from a single sheet of bronze by means of heating and hammering," said an IAA statement. "This technique made it possible to reduce its weight without diminishing its capacity for protecting the head of a warrior." The "helmet probably belonged to a Greek warrior stationed on one of the warships of the Greek fleet that participated in the naval conflict against the Persians who ruled the country at the time" said Koby Sharvit, director of the IAA marine unit.

© Israel Antiquities Authority

This bronze helmet was likely worn by a soldier fighting in the Greek-Persian wars

© John Hardin, IceCube/NSF

The surface portion of the IceCube Neutrino Observatory at the Amundsen-Scott South Pole Station in Antarctica

SPACE

Monster antimatter particle slams into Antarctica

Words by **Rafi Letzter**

The most remote particle detector on Earth has detected the most energetic antimatter particle ever: a single ultralight particle that smacked into the Antarctic ice with the thundering energy of 6,300 flying mosquitos. The collision occurred in 2016, but researchers only confirmed the details of the event in March 2021.

This antineutrino, an antimatter counterpart of the wispy, difficult-to-detect particle known as a neutrino, collided with an electron in the ice of Antarctica at nearly the speed of light. That collision created a shower of particles detected by the buried IceCube Neutrino Observatory, a facility responsible for much of the important high-energy neutrino research of the last decade. Now IceCube physicists report that the particle shower included evidence of a long-theorised but never-before-seen event known as Glashow resonance.

Back in 1960, the physicist Sheldon Glashow, then a postgraduate researcher at the Nordic Institute for Theoretical Physics in Denmark, predicted that when a sufficiently high-energy antineutrino collided with an electron, it would produce a heavy, short-lived particle known as a W boson. Glashow's prediction relied on the fundamental rules of the Standard Model of particle physics, a theory that dominates how researchers understand everything from the inside of atoms to light to antimatter. Actually detecting Glashow resonance is a powerful confirmation of the Standard Model. But it requires the neutrino to carry far more energy than any particle accelerator can produce: 6.3 petaelectronvolts (PeV).

It's usually difficult to wrap your mind around the numbers involved in high-energy particles. A single neutrino has a mass of about 2 billion-billion-billion-billionths of a gram, and thousands of low-energy neutrinos from the Sun pass through your body every second of the day without noticeable effects. But a neutrino with 6.3 petaelectronvolts of energy is another beast entirely.

> "Neutrinos pass through your body every second"

To put it into perspective, a teraelectronvolt (TeV) is equivalent to the energy of a single mosquito flying at one mile per hour. 6.3 PeV is 6,300 TeV, so turn that single mosquito into a swarm of 6,300 – or accelerate the single mosquito to Mach 8.2, more than four times the top speed of an F-16 – and you've got the energy of the single infinitesimal particle required for Glashow's resonance.

There's another way to think of 6.3 PeV: it's 450 times the maximum energy that the Large Hadron Collider, CERN's 17-mile-long multi-billion-dollar accelerator, responsible for the detection of the Higgs boson, should be able to produce by the late 2020s following ongoing upgrades.

This photo shows an Arctic walrus, like the one recently spotted in Ireland

© Getty

ANIMAL

Napping Arctic walrus wakes up in Ireland

Words by **Nicoletta Lanese**

A walrus spotted on an Irish beach on 14 March may have floated there from the Arctic Circle after falling asleep on an iceberg. A five-year-old girl walking with her father spotted the blubbery newcomer. The young girl, named Muireann, pointed out the walrus to her dad, Alan Houlihan, as they walked on Valentia Island in County Kerry. "I thought it was a seal at first, and then we saw the tusks," Houlihan said. "He kind of jumped up on the rocks. He was massive. He was about the size of a bull or a cow."

Most walruses (*Odobenus rosmarus*) live near the Arctic Circle, where they hunt for shellfish in shallow water and clamber up onto the icebergs and beaches to rest. The humongous creatures rarely crop up along the Irish shoreline. The first recorded walrus sighting there occurred in 1897, but no other walruses were seen until the 1980s. Since then, fewer than two dozen additional walruses have been spotted in Ireland.

The washed-up walrus spotted on Valentia Island is thought to be quite young, based on the length of the animal's tusks. Full-grown walruses can grow tusks as long as one metre, while the recently sighted walrus' tusks were roughly about 30 centimetres long. The walrus' body measured more than two metres from snout to tail.

But just how does a young walrus end up all the way in County Kerry? "I'd say what happened is he fell asleep on an iceberg and drifted off, and then he was gone too far, out into the mid-Atlantic or somewhere like that, down off Greenland possibly," said Kevin Flannery, a marine biologist with the Dingle Oceanworld Aquarium. "He could also be island-hopping and went to Iceland and on to Shetland, but that's unlikely. I'd say he came in out of the Atlantic." After travelling thousands of miles from his home in the Arctic, the walrus is likely exhausted and hungry.

STRANGE NEWS

Plague of mice ravages eastern Australia

Words by **Brandon Specktor**

Mice in the cabinets. Mice in the streets. Thousands upon thousands of mice in the barn, pooping so much it takes six hours to clean up their waste. These are scenes from Queensland and New South Wales, Australia, where an out-of-control mouse infestation is making life miserable for farmers, grocers and other citizens of the eastern Australian states. One farmer described the rodent frenzy as "an absolute plague," more severe than anything locals have seen in decades.

Some farmers have already lost entire grain harvests to the rampaging mice, according to local media reports, while hotels have had to close because they can't keep the critters out of the rooms. Staff at a grocery store in a small town northwest of Sydney reported catching as many as 600 mice a night. So far at least three people have visited the hospital with rodent bites. A researcher at the Commonwealth Scientific and Industrial Research Organisation said that the infestation is likely the result of an unusually large grain harvest, drawing more hungry mice to the area's farms earlier in the season than usual.

Locals have responded by laying extra traps, while one farmer in Queensland was given permission to use a drone to drop poison bait on the mice from above. Alan Brown, a farmer from the city of Wagga Wagga, said that the plague was likely just beginning, considering the rapid pace of breeding in mice.

© Getty

Some locals are spending six hours a day cleaning up mouse poop

SPACE

The ISS dumps 2.6-tonne hunk of space junk

Words by **Mike Wall**

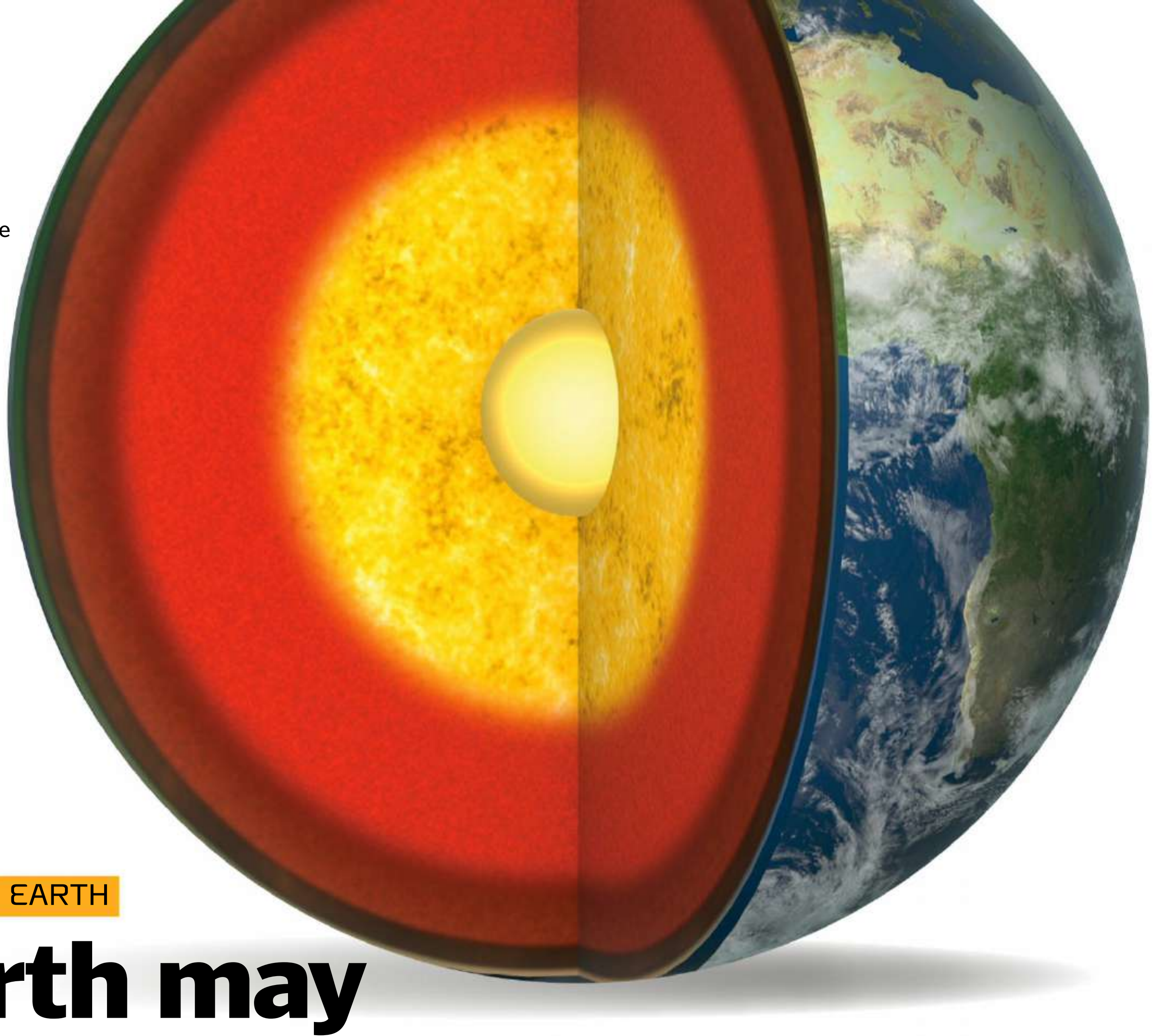
The orbiting lab discarded a 2.6-tonne pallet of used batteries on 11 March, the most massive object it has ever jettisoned. The space junk is expected to fall back to Earth in two to four years. The pallet should burn up 'harmlessly in the atmosphere', but not everyone is convinced that's the case. "This strikes me as dangerous. It seems big and dense, so unlikely to burn up completely," tweeted astronomer and author Phil Plait.

"On the other hand, Tiangong-1 was 7,500 kilograms, much bigger. But I would say given how dense EP9 is, it's concerning," responded astrophysicist Jonathan McDowell, based at the Harvard-Smithsonian Center for Astrophysics. EP9, short for 'Exposed Pallet 9', is the recently jettisoned object. EP9 came to the station last year on a Japanese H-II Transfer Vehicle (HTV) as part of the effort to replace the orbiting lab's old nickel-hydrogen batteries with lithium-ion ones.

Batteries were packed into the HTV, which carried them down to their doom in Earth's atmosphere. But the October 2018 launch failure of a Soyuz rocket carrying Nick Hague and Alexey Ovchinin disrupted this. EP9 came up on the ninth and final HTV, meaning it was left without a doomsday ride. Space station managers instead decided to jettison the battery-packed pallet, and ground controllers at NASA's Johnson Space Center in Houston commanded the orbiting lab's 17.6-metre robotic arm to release EP9 into orbit.

© NASA

The ISS jettisoned a 2.6-tonne pallet carrying used batteries on 11 March 2021



Earth is made up of three layers

© Getty

PLANET EARTH

Earth may have a hidden core

Words by **Stephanie Pappas**

New research finds that there may be a hidden layer inside the Earth's solid inner core – an inner-inner core, if you will. The precise nature of this layer is mysterious, but it could have something to do with changes in the structure of iron under extreme temperatures and pressures. A study revealed that there is more complexity to the inner core than previously appreciated, said Jo Stephenson, a doctoral student in seismology at Australian National University in Canberra: "It's not just a solid ball of iron".

Earth's core comes in two parts. The liquid outer core starts about 1,800 miles from the surface of Earth and is made of liquid metals at temperatures of 2,204 to 4,982 degrees Celsius. At about 3,200 miles below Earth's surface, the core transitions to solid iron, and a bit of nickel.

The first inklings that there might be something interesting lurking at the centre of the inner core came as far back as the 1980s. Because there's no way to get to the inner core, where temperatures approach those found at the surface of the Sun, scientists use earthquake waves to make images of the core. Waves from an earthquake on one side of the planet that are detected on the other side of the planet carry subtle changes that scientists can use to recreate an image of what they've passed through.

Strangely, when waves pass through the core from north to south, they travel faster than waves passing through the core parallel to the Earth's equator. No one knows why this is, but it's a consistent finding. The technical term for this oddity is anisotropy. At the very centre of the inner core something seems to be different, which scientists noticed in the early 2000s. At this depth, the anisotropy seemed not to match that of the rest of the inner core.

Stephenson and her colleagues brought together a dataset of about 100,000 earthquake waves that passed through this level of the core and applied an algorithm that searches for the best physical explanation of what's going on to explain the data. What they found was that in the inner-inner core, starting about 400 miles from the centre of Earth, the anisotropy in the slow direction isn't quite parallel with the equator anymore, but 54 degrees off. "This isn't just noise in the data… this is really something that's there," Stephenson said.

But it's not easy to say what that something is. The researchers are now working with mineral physicists and geodynamicists to try to come up with models of the inner-inner core that would explain this change. As the planet spins, the inner core is cooling and expanding, so the inner-inner core structure could have something to do with the way iron crystallises as it cools, or it could be due to changes in the way the metal behaves at great temperatures and pressures.

The core is important to understand, Stephenson said, because its swirling interactions create Earth's magnetic field. The magnetic field shields the planet from charged particles streaming from the Sun. This protection enabled the evolution of life. "It's really, really important."

SPACE

Super-Earth has super-fast orbit

Words by **Mike Wall**

We keep getting reminders that the Milky Way's planetary diversity dwarfs what we see in our own Solar System. The newfound exoplanet TOI-1685 b is yet another case in point. Astronomers found it circling a dim red dwarf star about 122 light years from Earth. 'Circling' is much too ordinary a word for TOI-1685 b's motion, however, as the alien world whips around its parent star once every 0.67 Earth days.

Red dwarfs, also known as M dwarfs, are much smaller and dimmer than Earth's Sun, but TOI-1685 b's extreme proximity to its host star, called TOI-1685, makes it a very toasty world nonetheless. The discovery team estimates its surface temperature to be around 796 degrees Celsius.

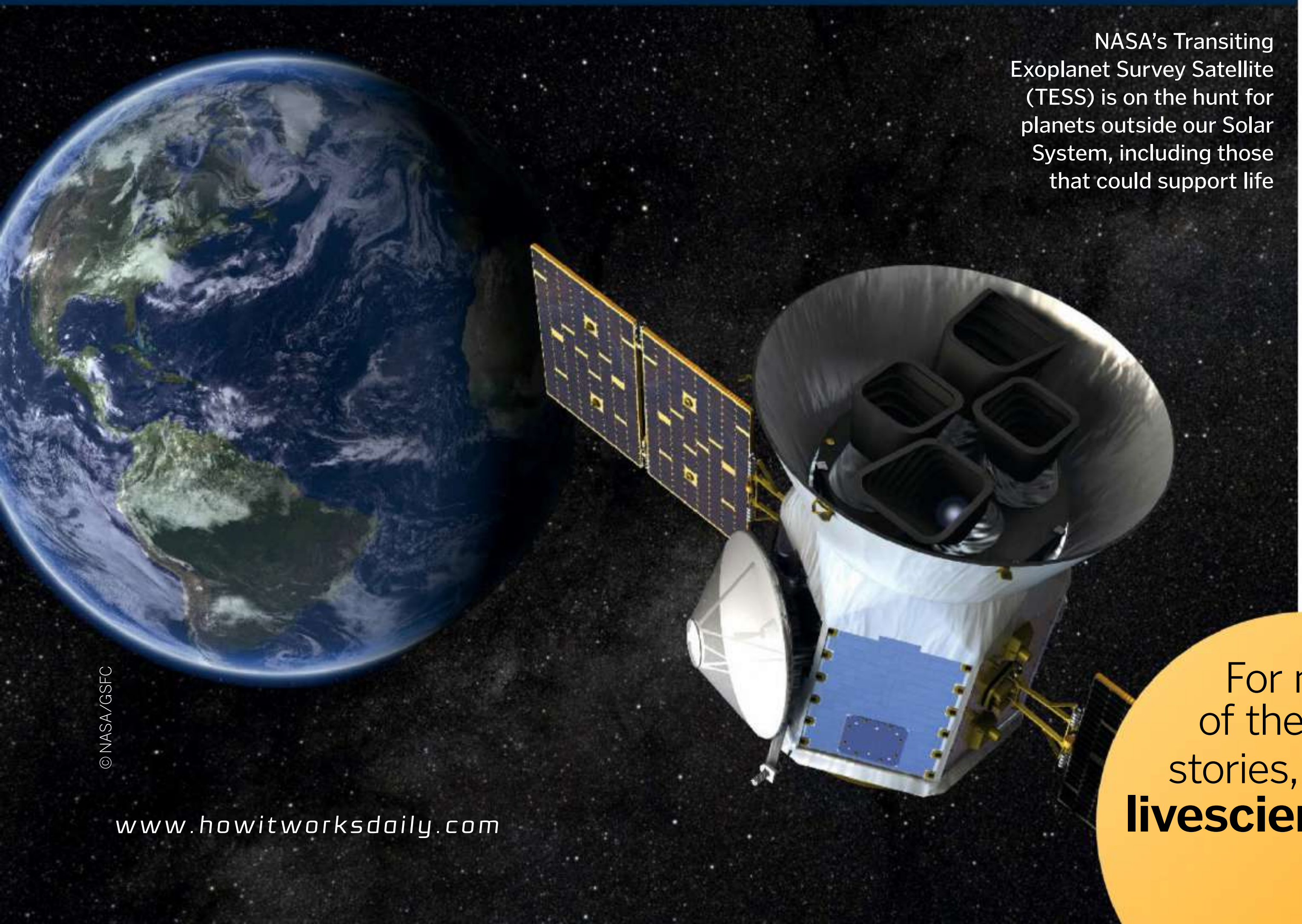
Researchers first spotted TOI-1685 b in observations made by NASA's Transiting Exoplanet Survey Satellite (TESS). As its name suggests, TESS looks for transits – the tiny dips in brightness caused by planets crossing their host stars' faces from the Earth-orbiting spacecraft's perspective.

TESS noted such a dip around the red dwarf TOI-1685. A team of astronomers then confirmed the planet's existence using data gathered by the CARMENES spectrograph instrument, which is installed on the 3.5-metre telescope at the Calar Alto Observatory in Spain. CARMENES is short for Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Echelle Spectrographs. This instrument hunts for planets using the radial velocity, or Doppler method, looking for little wobbles in a star's motion caused by the gravitational tug of an orbiting planet.

The combined data allowed researchers to determine that TOI-1685 b is a super-Earth about 1.7 times bigger and 3.8 times more massive than our home planet. The resulting bulk density, about 4.2 grams per cubic centimetre, makes TOI-1685 b the least dense ultra-short-period planet around an M dwarf discovered to date. For some perspective, Earth's bulk density is about 5.5 grams per cubic centimetre.

The fact that TOI-1685 b transits and is quite warm makes it a good candidate for follow-up studies by other instruments. In that regard, TOI-1685 b is similar to another recent exoplanet find made using TESS and CARMENES data, Gliese 486 b.

> "Researchers first spotted TOI-1685 b in observations made by TESS"



NASA's Transiting Exoplanet Survey Satellite (TESS) is on the hunt for planets outside our Solar System, including those that could support life

© NASA/GSFC

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Pfizer-BioNTech COVI
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For use under Emergency
DILUTE BEFORE USE
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PAA156
EXPIRATION DATE

© The Smithsonian Institution's National Museum of American History

The vaccine vial used for the historic first COVID-19 shot in the US has been acquired by the Smithsonian's National Museum of American History

HEALTH

First US COVID-19 vaccine vial headed to museum

Words by **Rachael Rettner**

When a New York nurse became the first American to receive a dose of an FDA-authorised COVID-19 vaccine in December 2020, it was a moment that would go down in history. Now that first vaccine vial is heading to a history museum to be displayed in an exhibit planned for next year.

On 10 March 2021, the Smithsonian's National Museum of American History announced that it had acquired the now-empty vial of the Pfizer-BioNTech vaccine used for that historic shot, which was administered to intensive-care nurse Sandra Lindsay on 14 December 2020. Other materials, including Lindsay's vaccination record card, scrubs and hospital identification badge, will also become part of the museum's collection.

The materials were donated by Northwell Health, the New York healthcare provider where Lindsay works. Northwell Health also donated other materials connected to the first vaccine doses, including the special shipping materials that were needed to maintain the vaccines at ultra-cold temperatures. "These now-historic artefacts document not only this remarkable scientific progress, but represent the hope offered to millions living through the cascading crises brought on by COVID-19," said Anthea M. Hartig, the museum's director.

Since April 2020, the museum has been collecting artefacts to document the pandemic and its effects on society. Some of the artefacts volunteered to the museum include rubbish bags that healthcare workers wore when supplies of protective gear were low, and signs that people made to show support to their loved ones who were locked down in assisted care facilities.

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livescience.com

WISH LIST

The latest **educational robots**

Robotics Smart Machines

■ Price: **£110 / $134.95**
www.thamesandkosmos.co.uk / store.thamesandkosmos.com

If you're looking for an introduction to robotics, this kit is for you. Simple and fun to use, this customisable kit allows children the ability to program and control eight different motorised machines. With its ultrasonic sensors, users can program their designs to detect and respond to objects around them using a similar method to bat echolocation. Not only can you learn about how to program movement and interactions, but you can also gain an insight into the technology used to build them.

EXPERIMENT KIT
8-14
ENGINEERING KIT
ROBOTICS
SMART MACHINES
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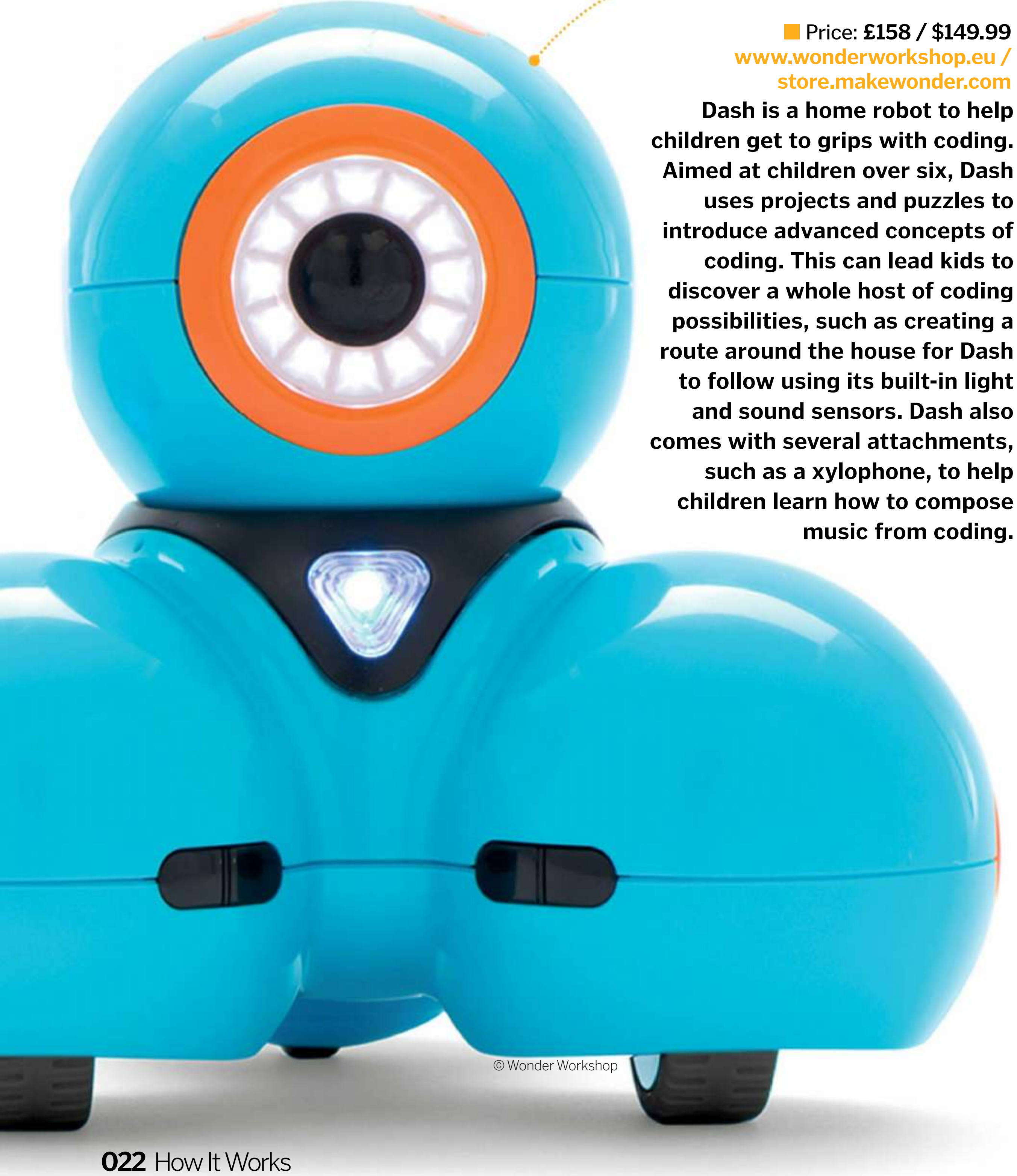
→ PROGRAM AND CONTROL YOUR ROBOTS WITH TABLETS AND SMARTPHONES
→ AN ULTRASONIC SENSOR ENABLES THE ROBOTS TO REACT TO THEIR SURROUNDINGS
Play It Smart
230
8

© Thames and Kosmos

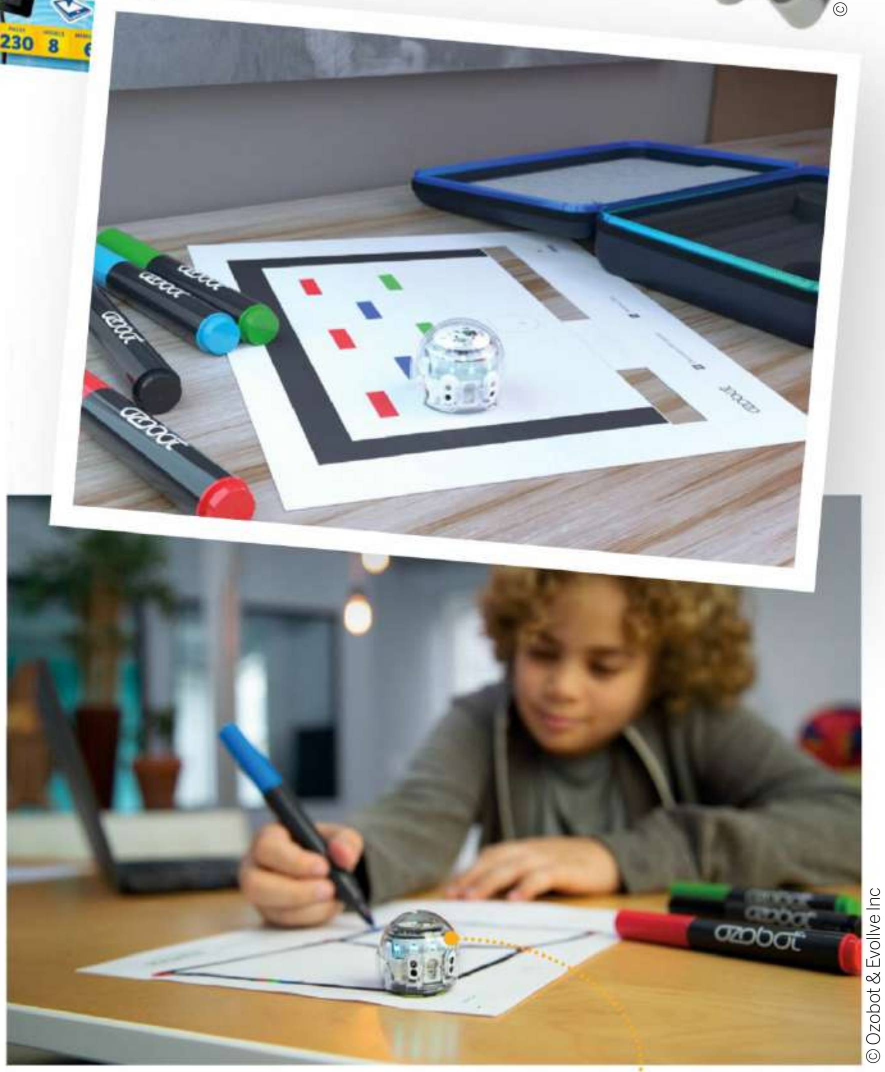
Dash

■ Price: **£158 / $149.99**
www.wonderworkshop.eu /
store.makewonder.com

Dash is a home robot to help children get to grips with coding. Aimed at children over six, Dash uses projects and puzzles to introduce advanced concepts of coding. This can lead kids to discover a whole host of coding possibilities, such as creating a route around the house for Dash to follow using its built-in light and sound sensors. Dash also comes with several attachments, such as a xylophone, to help children learn how to compose music from coding.



© Wonder Workshop

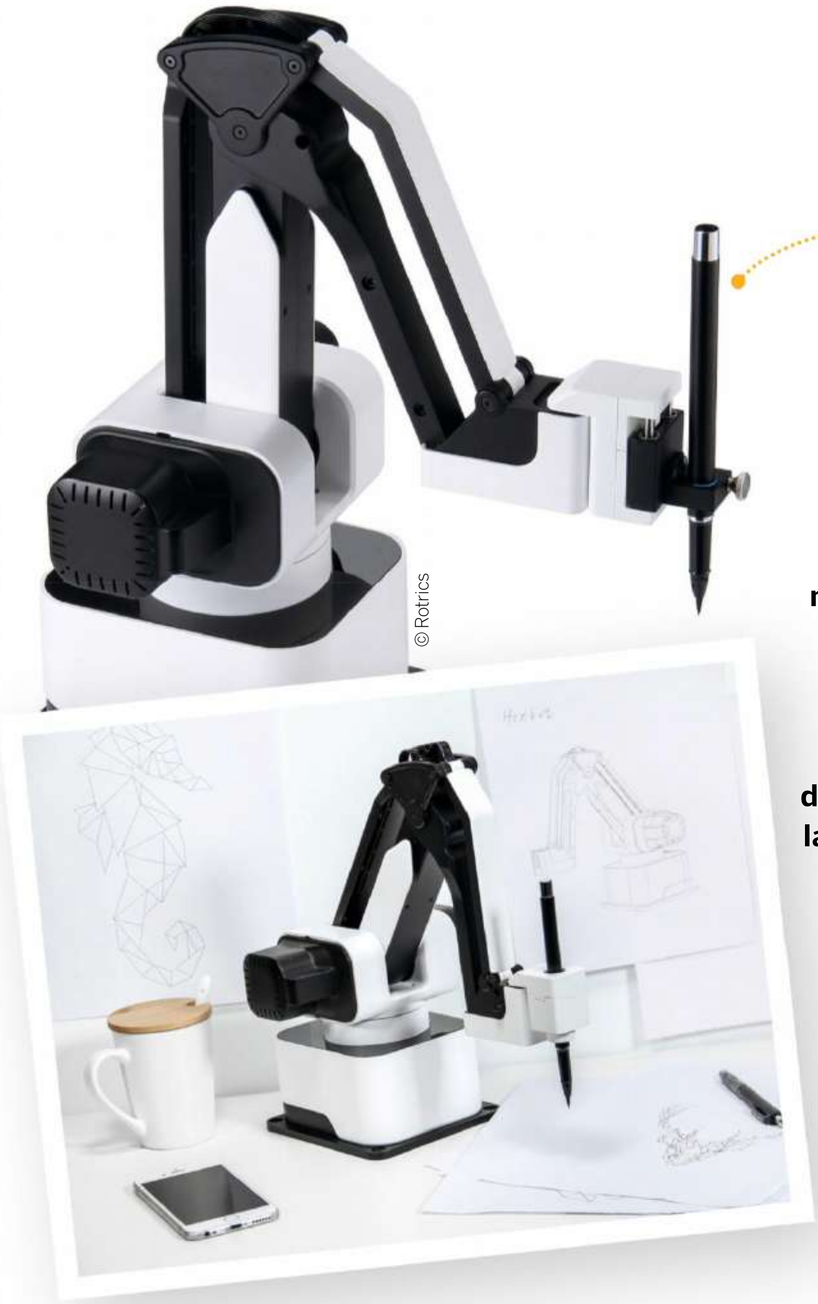


© Ozobot & Evollve Inc

Evo

■ Price: **From $99 (approx. £71)**
shop.ozobot.com

This little robot on wheels combines interactive coding with fun challenges and games. Evo by Ozobot is a pocket-sized robot that uses sensors to interact with lines and colours drawn in marker pen. Evo can follow along line paths and intercept different colours as actions, such as speed and direction. The accompanying app also provides users with different challenges to expand their coding and mechanical knowledge to increasing levels of difficulty.



© Rotrics

DexArm

Price: From $799 (approx. £575)
www.rotrics.com

Meet the DexArm by Rotrics, the desktop robotic arm. This futuristic machine allows you to interact with its many interchangeable modules for drawing, laser engraving, 3D printing and much more. If you're looking to cross over your artistic skills into computer design, then this high-tech robot can help you achieve your goals. Easy-to-use software allows you to code or sketch your digital designs and create them at home. This is a lavish creative tool to discover new coding and computer-aided design possibilities.

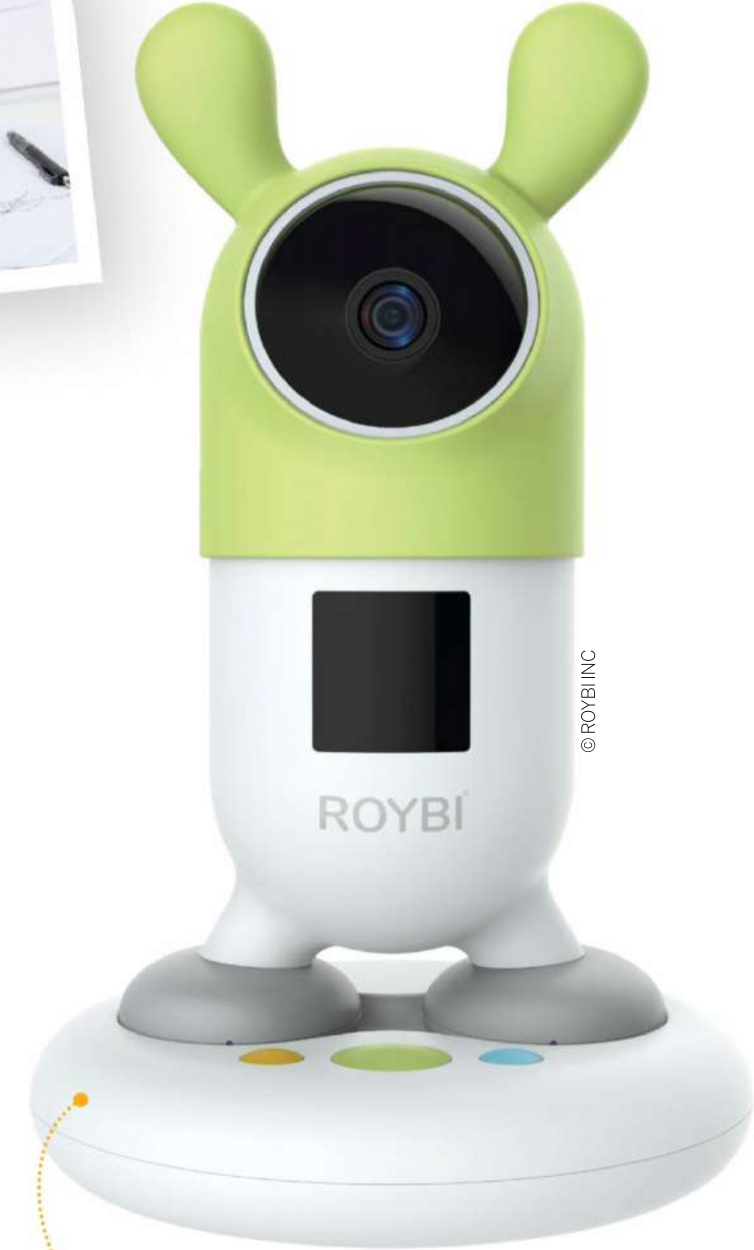
The Cubelets Discovery Set

Price: $139 (approx. £100)
www.modrobotics.com

If you combine the assembling fun of LEGO with computer programming, you get Cubelets by Modular Robotics. This discovery kit is filled with small robotic building blocks called Cubelets, which have been created to give budding engineers the opportunity to get creative with computer programming. Each Cubelet serves a different purpose: SENSE cubes can take information from their environment, such as touch, then THINK cubes compute that information and send it to the ACT Cubelets, which turn that information into physical action.

cubelets
4+
Discovery Set
Discovery Guide

© Modular Robotics



© ROYBI INC

ROYBI Robot

Price: $299.95 (approx. £215)
www.roybirobot.com

ROYBI is an educational robot that helps children with a whole host of subjects, such as maths, science, literature and language. The companion app allows parents to set out weekly lessons and check progress remotely. ROYBI can recognise a child through its face detection and voice recognition to begin conservations or start a lesson. This compact robot lasts around eight hours once charged and is drop resistant, allowing time to learn and play.

APPS & TOOLS

Khan Academy Kids

Developer: Khan Academy
Price: Free / Google Play / App Store

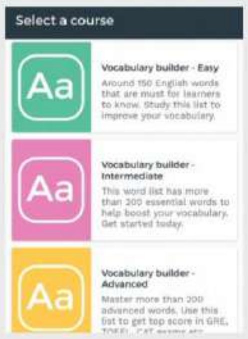
This award-winning app is packed with activities, lessons, books, songs and games to help your child learn new skills and expand their knowledge.

New books and lessons for first and second grade

Improve English

Developer: Knudge
Price: Free / Google Play / App Store

If you're looking to broaden your vocabulary or improve grammar, this app helps you achieve your goals through flashcards, classes and games.



Select a course

Vocabulary builder - Easy
Around 150 English words that are must for learners to know. Study this list to improve your vocabulary.

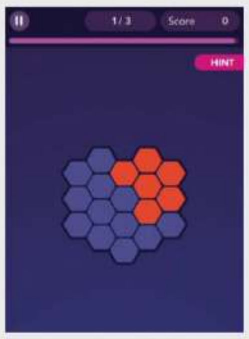
Vocabulary builder - Intermediate
This word list has more than 200 essential words to help boost your vocabulary. Get started today.

Vocabulary builder - Advanced
Master more than 200 advanced words. Use this list to get top score in GRE,

MindPal

Developer: Elektron Labs Inc
Price: Free / Google Play / App Store

This daily brain-training app features over 35 games and 100 levels that challenge your memory, attention, language and problem solving.



Tech Quotient

Developer: Mouser Electronics Inc
Price: Free / Google Play

Put your technology, science and maths to the test with this fun and thought-provoking quiz app. Earn points to climb the leaderboard and impress your friends.

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32,728
TOTAL SCORE
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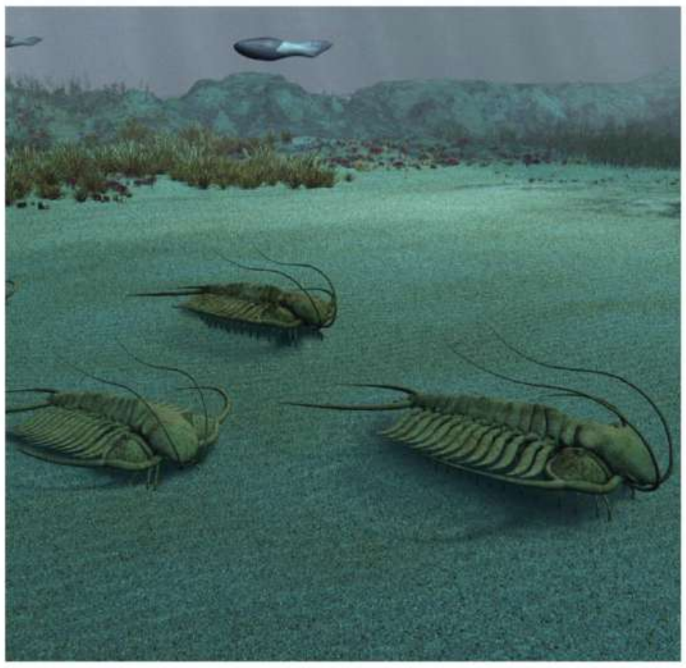
MASS EXTINCTION

THE DEATH OF THE DINOSAURS WAS JUST ONE OF FIVE GLOBAL EVENTS THAT SAW MILLIONS OF SPECIES WIPED OUT – HOW DO THESE EVENTS HAPPEN?

Words by **Scott Dutfield**



© Alamy

By the end of the Ordovician Period the seafloor was teeming with shelled creatures such as trilobites

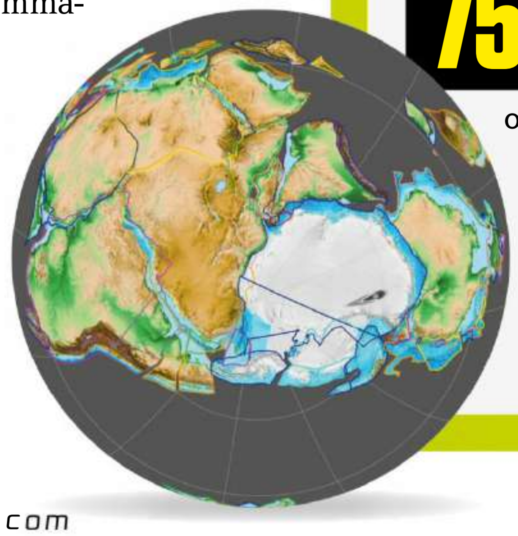
Ordovician-Silurian extinction

AROUND 440 MILLION YEARS AGO

Species made extinct
85%

The first mass extinction occurred when life itself was still in its infancy. Organisms such as corals and shelled brachiopods filled the world's shallow waters, but hadn't yet ventured onto land. When a climatic shift caused sea temperatures to change, the majority of life in the ocean died. By the end of the Ordovician Period, the rapid onset of mass glaciation covered the southern supercontinent, Gondwana. Glaciation on this scale locked away high percentages of the world's water and dramatically lowered global sea levels, which stripped away vital habitats from many species, destroying food chains and decreasing reproductive success. It's thought that the cooling process may have been triggered by the formation of the North American Appalachian Mountains. Large-scale erosion of these mountainous silicate rocks is associated with the removal of carbon dioxide from the atmosphere, which keeps the planet warm.

Alternative theories suggest that toxic metal may have dissolved into ocean waters during a period of oxygen depletion, wiping out marine life. Others suggest that a gamma-ray burst from a supernova ripped an enormous hole in the ozone layer, allowing deadly ultraviolet radiation to kill life below.

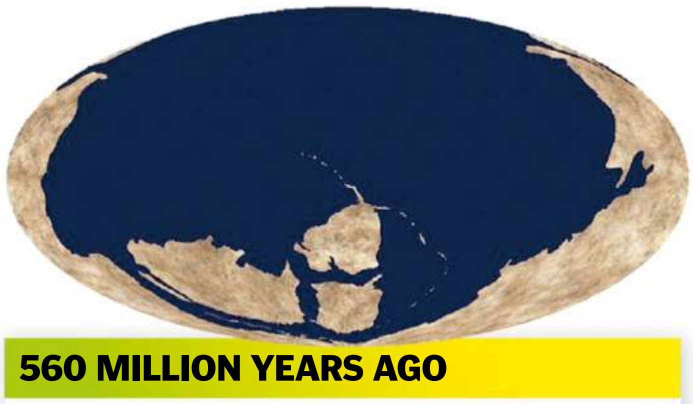


The supercontinent Gondwana reached the South Pole by the late Ordovician Period

Source: Wiki/Fama Clamosa

Gondwana moves south

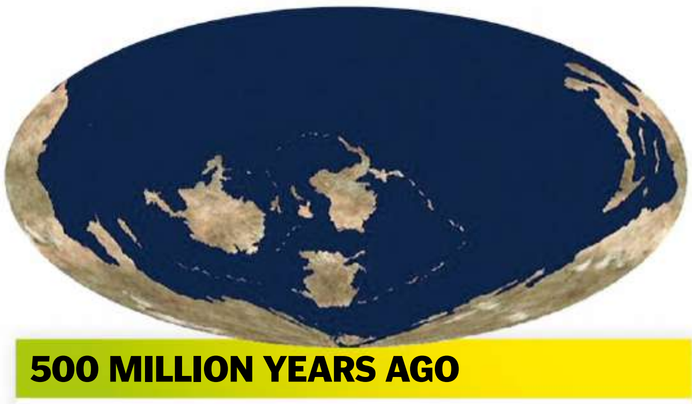
How a supercontinent changed life on Earth



560 MILLION YEARS AGO

Thawing out

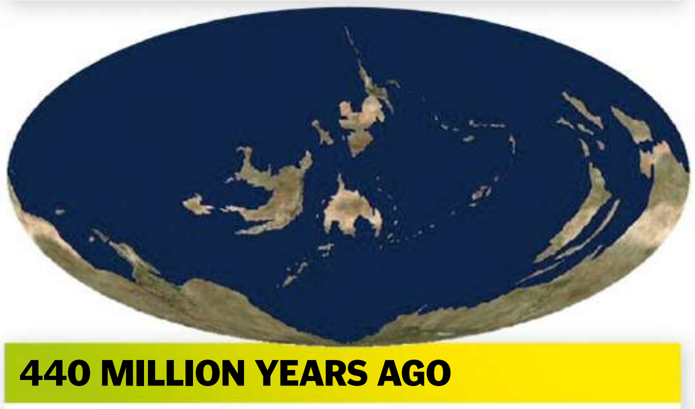
The Earth began to thaw out after a global ice age, flooding areas of land with water and raising global sea levels. This allowed marine life to flourish and diversify.



500 MILLION YEARS AGO

Heading southward

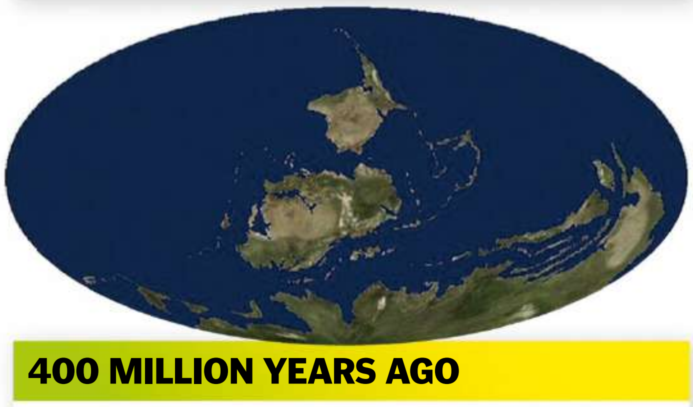
The supercontinent Gondwana, made up of present-day South America, Africa, Arabia, Madagascar, India, Australia and Antarctica, gathered at the South Pole.



440 MILLION YEARS AGO

Glaciation

Mass glaciation carved into Gondwana and caused sea levels to sink, reducing habitats and decreasing ocean oxygen. This led to the first mass extinction of marine life.

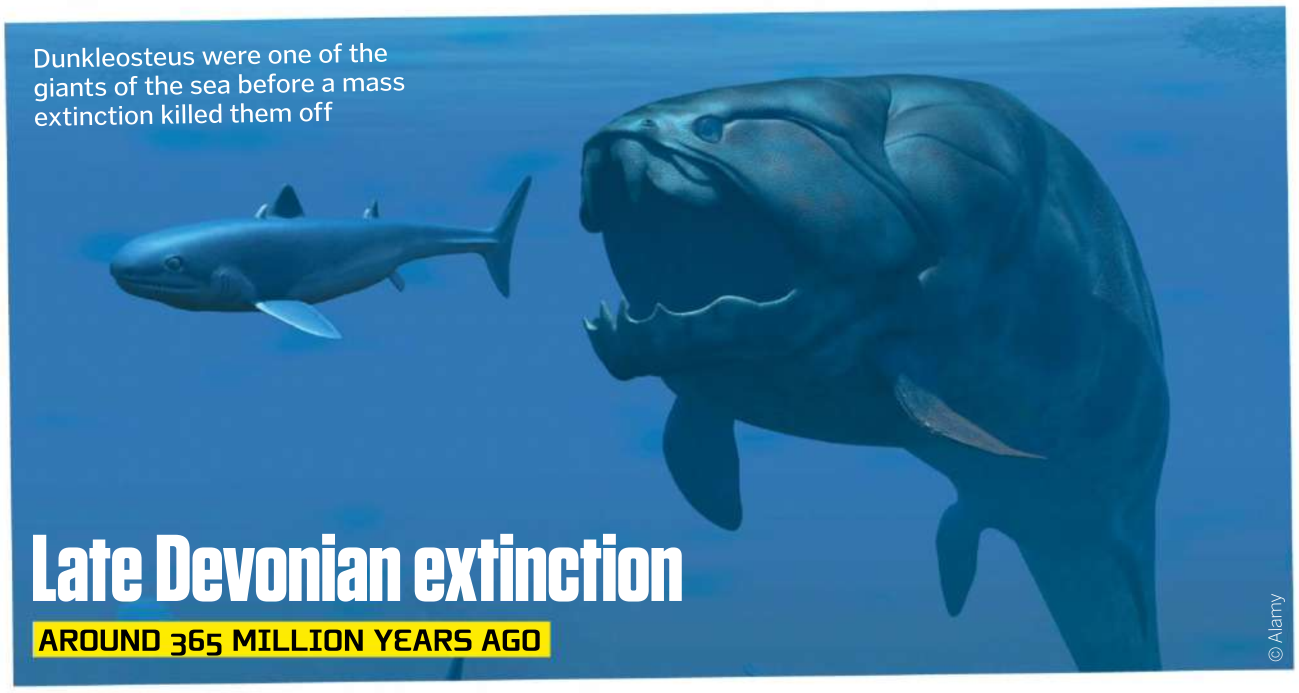


400 MILLION YEARS AGO

New life

Gondwana thawed and ascended to the equator. Diverse marine life returned to the oceans, and some species evolved to live on land, such as the first known insects.

© The Planetary Habitability Laboratory @ UPR Arecib



Dunkleosteus were one of the giants of the sea before a mass extinction killed them off

© Alamy

Late Devonian extinction

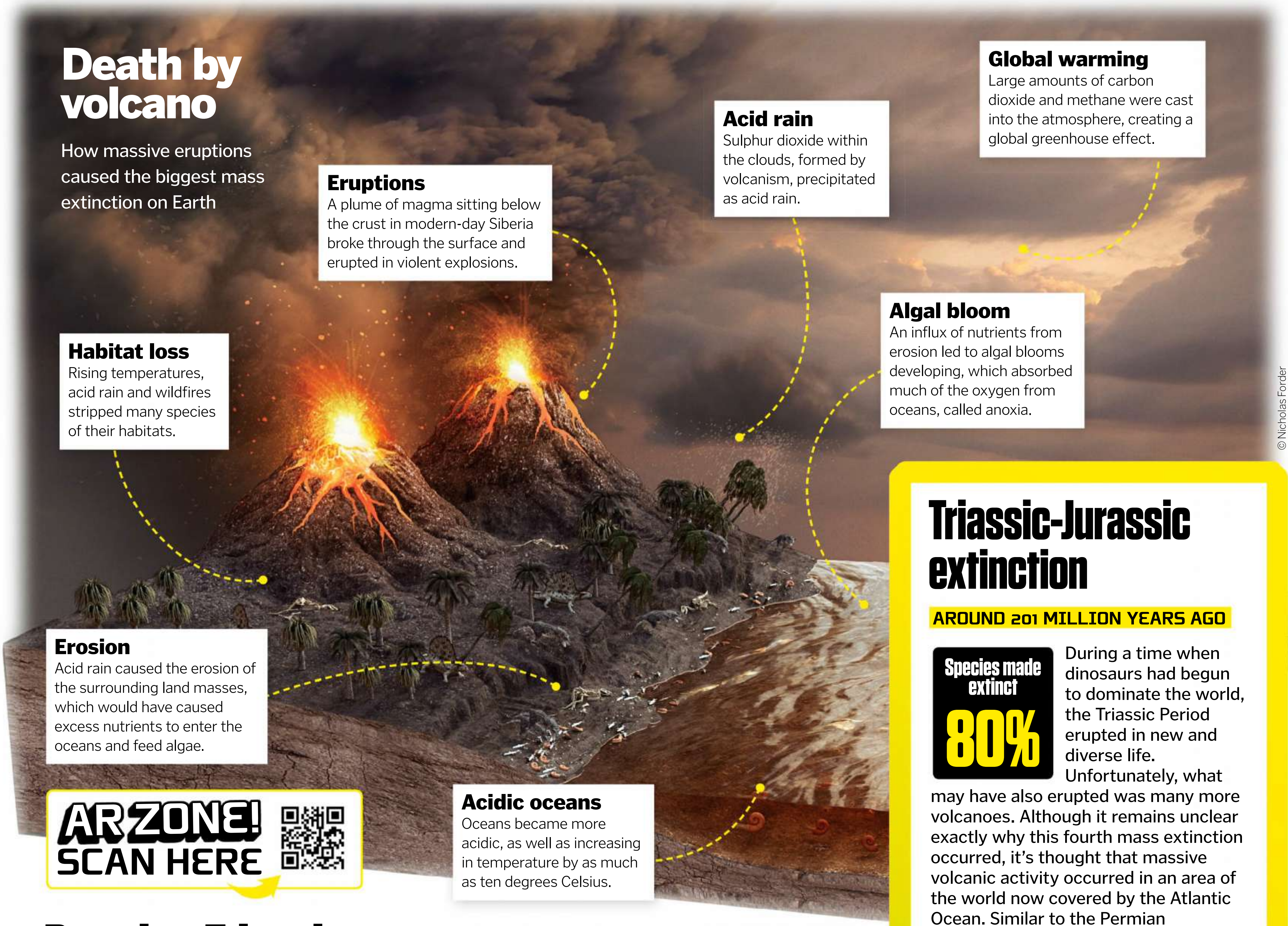
AROUND 365 MILLION YEARS AGO

Species made extinct
75%

Often referred to as the 'age of fish', the Devonian Period saw the rise and fall of many prehistoric marine species. Although by now animals had begun to evolve on land, the majority of diverse life swam through the oceans. That was until vascular plants, such as trees and flowers, caused a second mass extinction. As plants evolved roots, they inadvertently transformed the land they lived on, turning rock and rubble into soil. This nutrient-rich soil then ran into the world's oceans, causing algae to bloom on an enormous scale. This essentially created giant 'dead zones', which are areas where algae strips oxygen from the water, suffocating marine life and wreaking havoc on marine food chains. Species that were unable to adapt to the decreased oxygen levels and lack of food died. One such sea monster that was wiped from the world's oceans was a ten-metre-long armoured fish called Dunkleosteus. As a fearsome predator, this giant fish had a helmet of bone plates that covered its entire head and created a fang-like cusp on its jaw.

Death by volcano

How massive eruptions caused the biggest mass extinction on Earth



Eruptions
A plume of magma sitting below the crust in modern-day Siberia broke through the surface and erupted in violent explosions.

Acid rain
Sulphur dioxide within the clouds, formed by volcanism, precipitated as acid rain.

Global warming
Large amounts of carbon dioxide and methane were cast into the atmosphere, creating a global greenhouse effect.

Habitat loss
Rising temperatures, acid rain and wildfires stripped many species of their habitats.

Algal bloom
An influx of nutrients from erosion led to algal blooms developing, which absorbed much of the oxygen from oceans, called anoxia.

Erosion
Acid rain caused the erosion of the surrounding land masses, which would have caused excess nutrients to enter the oceans and feed algae.

Acidic oceans
Oceans became more acidic, as well as increasing in temperature by as much as ten degrees Celsius.

© Nicholas Forder

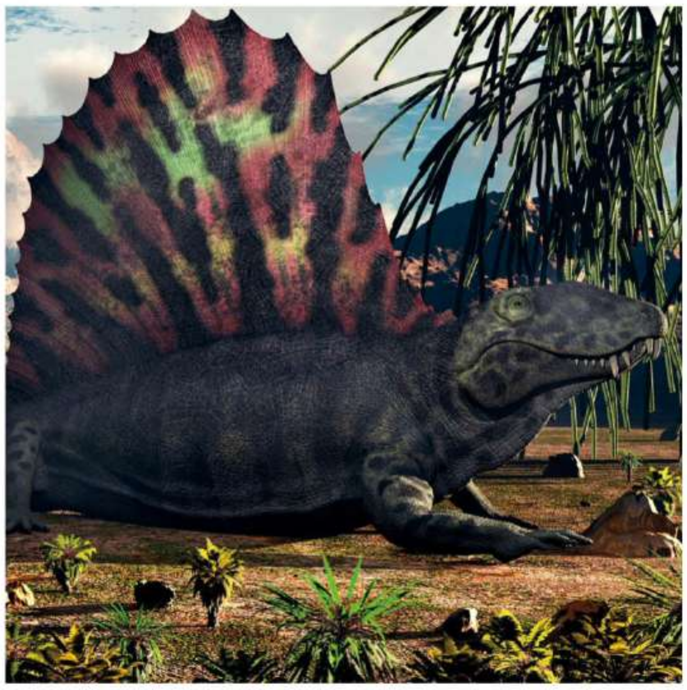
AR ZONE! SCAN HERE

Permian-Triassic extinction

AROUND 252 MILLION YEARS AGO

Species made extinct
96% marine life
70% terrestrial life

This extinction event, often referred to as the 'Great Dying', is the largest to ever hit Earth. It wiped out some 90 per cent of all the planet's species and decimated the reptiles, insects and amphibians that roamed on land. What caused this catastrophic event was a period of rampant volcanism. At the end of the Permian Period, the part of the world we now call Siberia erupted in explosive volcanoes. This released a large amount of carbon dioxide into the atmosphere, causing a greenhouse effect that heated up the planet. As a result, weather patterns shifted, sea levels rose and acid rain beat down on the land. In the ocean, the increased levels of carbon dioxide dissolved into the water, poisoning marine life and depriving them of oxygen-rich water. At the time the world consisted of one supercontinent called Pangaea, which some scientists believe contributed to a lack of movement in the world's oceans, creating a global pool of stagnant water that only perpetuated carbon dioxide accumulation. Corals were a group of marine life forms worst affected, it took 14 million years for the ocean reefs to rebuild to their former glory.



© Alamy

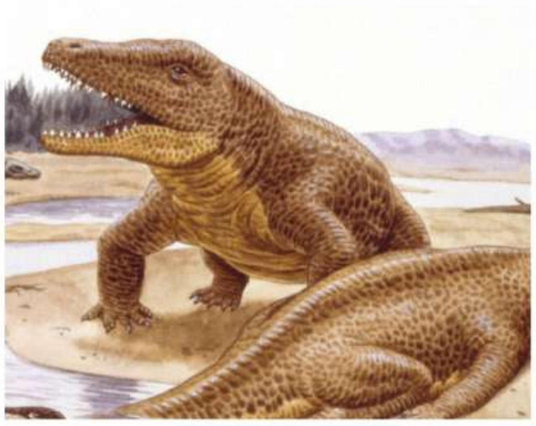
Some of the earliest land dinosaurs, such as dimetrodons, were among the first to become extinct

Triassic-Jurassic extinction

AROUND 201 MILLION YEARS AGO

Species made extinct
80%

During a time when dinosaurs had begun to dominate the world, the Triassic Period erupted in new and diverse life. Unfortunately, what may have also erupted was many more volcanoes. Although it remains unclear exactly why this fourth mass extinction occurred, it's thought that massive volcanic activity occurred in an area of the world now covered by the Atlantic Ocean. Similar to the Permian extinction, volcanoes released enormous amounts of carbon dioxide, forcing climate change and devastating life on Earth. Global temperatures increased, ice melted and sea levels rose and acidified. As a result, many marine and land species became extinct, including large prehistoric crocodiles and some flying pterosaurs. There are alternative theories that suggest rising carbon dioxide levels released trapped methane from permafrost, which would have resulted in a similar series of events that led to this mass extinction.



© Getty

Ticinosuchus was one of many species to go extinct at the start of the Jurassic Period

DID YOU KNOW? *The asteroid that killed the dinosaurs hit Earth at roughly 20 times the speed of a rifle bullet*

K-T extinction

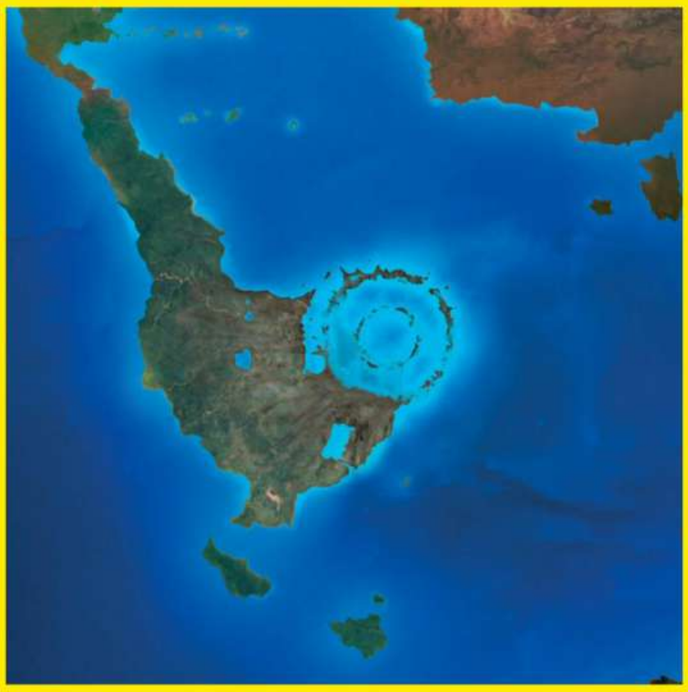
AROUND 66 MILLION YEARS AGO

Species made extinct
75%

The most famous of all five mass extinction events is the Cretaceous-Tertiary extinction – known better as the day the dinosaurs died. Geologists refer to the event as the 'K-T extinction' because the letter 'C' is shorthand for a previous geological period called the Cambrian.

Crash-landing into what is today Yucatán, Mexico, an asteroid over eight miles wide plunged into Earth at around 45,000 miles per hour. This punched a hole 110 miles wide and 12 miles deep, called the Chicxulub crater. The impact would have scorched all the land around it within 900 miles, and ended the 180-million-year reign of the dinosaurs on Earth.

What followed the impact was months of blackened skies caused by debris and dust being hurled into the atmosphere. This prevented plants from absorbing sunlight, they died out en masse and broke down the dinosaurs' food chains. It also caused global temperatures to plummet, plunging the world into an extended cold winter. It's estimated that it would have only taken months after the impact for most of the extinctions on Earth to occur. However, many species that could fly, burrow or dive to the depths of the oceans survived. For example, the only true descendants of the dinosaurs are modern-day birds – more than 10,000 species are thought to have descended from impact survivors.

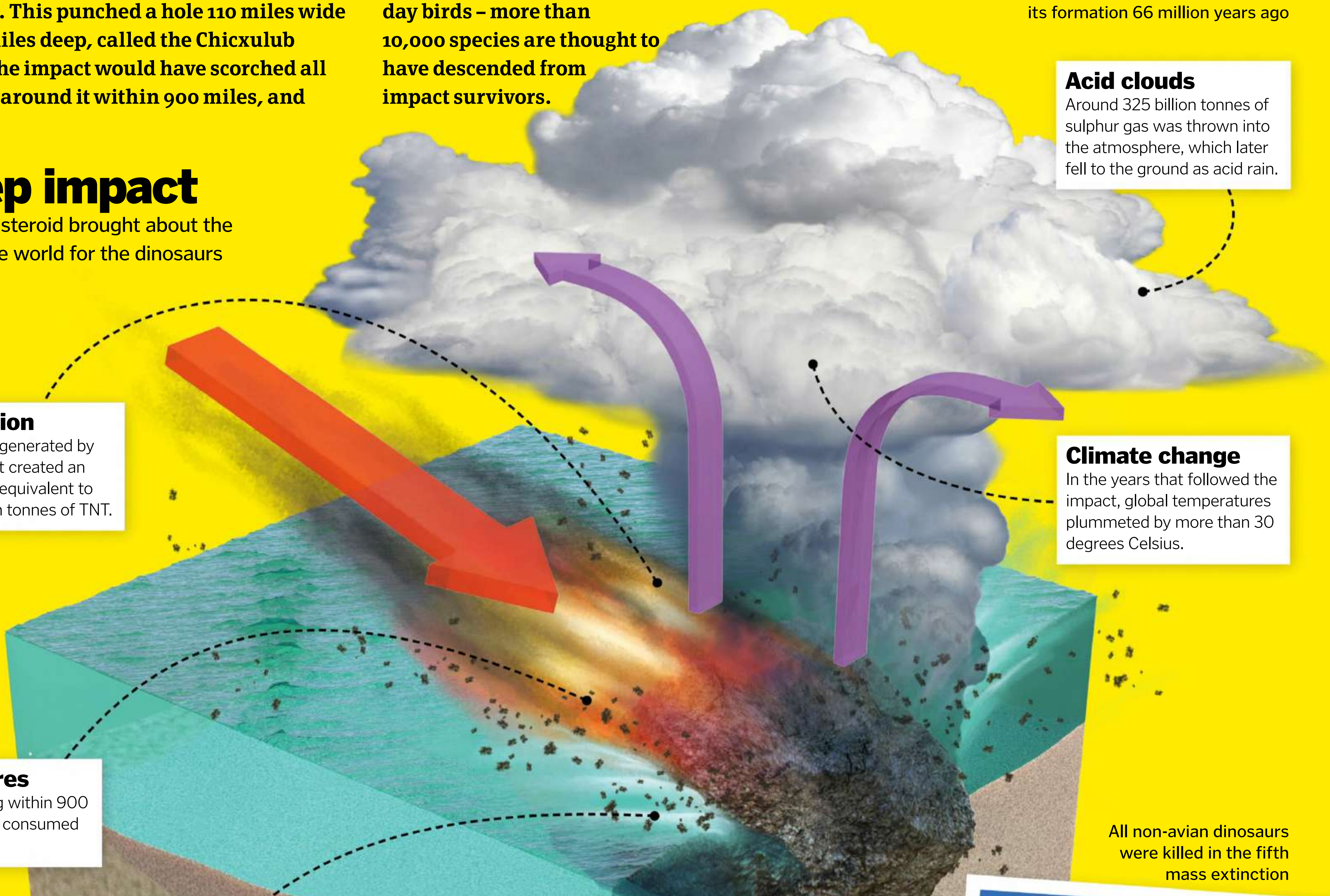


© Getty

An illustration of the Chicxulub crater shortly after its formation 66 million years ago

Deep impact

How an asteroid brought about the end of the world for the dinosaurs



Acid clouds
Around 325 billion tonnes of sulphur gas was thrown into the atmosphere, which later fell to the ground as acid rain.

Explosion
The force generated by the impact created an explosion equivalent to 100 trillion tonnes of TNT.

Climate change
In the years that followed the impact, global temperatures plummeted by more than 30 degrees Celsius.

Wildfires
Everything within 900 miles was consumed in flames.

Wall of water
Upon impact, tsunamis up to 300 metres high surged around the world.

Earthquakes
A magnitude 10 earthquake tore through the seafloor – a magnitude yet to be recorded in human history.

All non-avian dinosaurs were killed in the fifth mass extinction

© Getty

Pandas became the poster species for extinction back in the 1980s, when there were fewer than 1,114 individuals recorded in China

© Getty

Holocene extinction

AROUND 8,000 BCE TO PRESENT

Species made extinct

?

Also known as the sixth mass extinction, for the last 10,000 years Earth has been in the midst of another extinction event, which is rapidly removing animals from our planet.

Scientists define a mass extinction as around three-quarters of all species dying out over a short geological time, which is anything less than 2.8 million years. Right now we find ourselves at the beginning of the latest mass extinction, which is moving much faster than any of the others. Since 1970, the populations of vertebrate species have declined by an average of 68 per cent, and currently over 35,000 species are considered to be threatened with extinction. During the 20th century alone, as many as 543 land vertebrates became extinct.

ARE HUMANS TO BLAME?

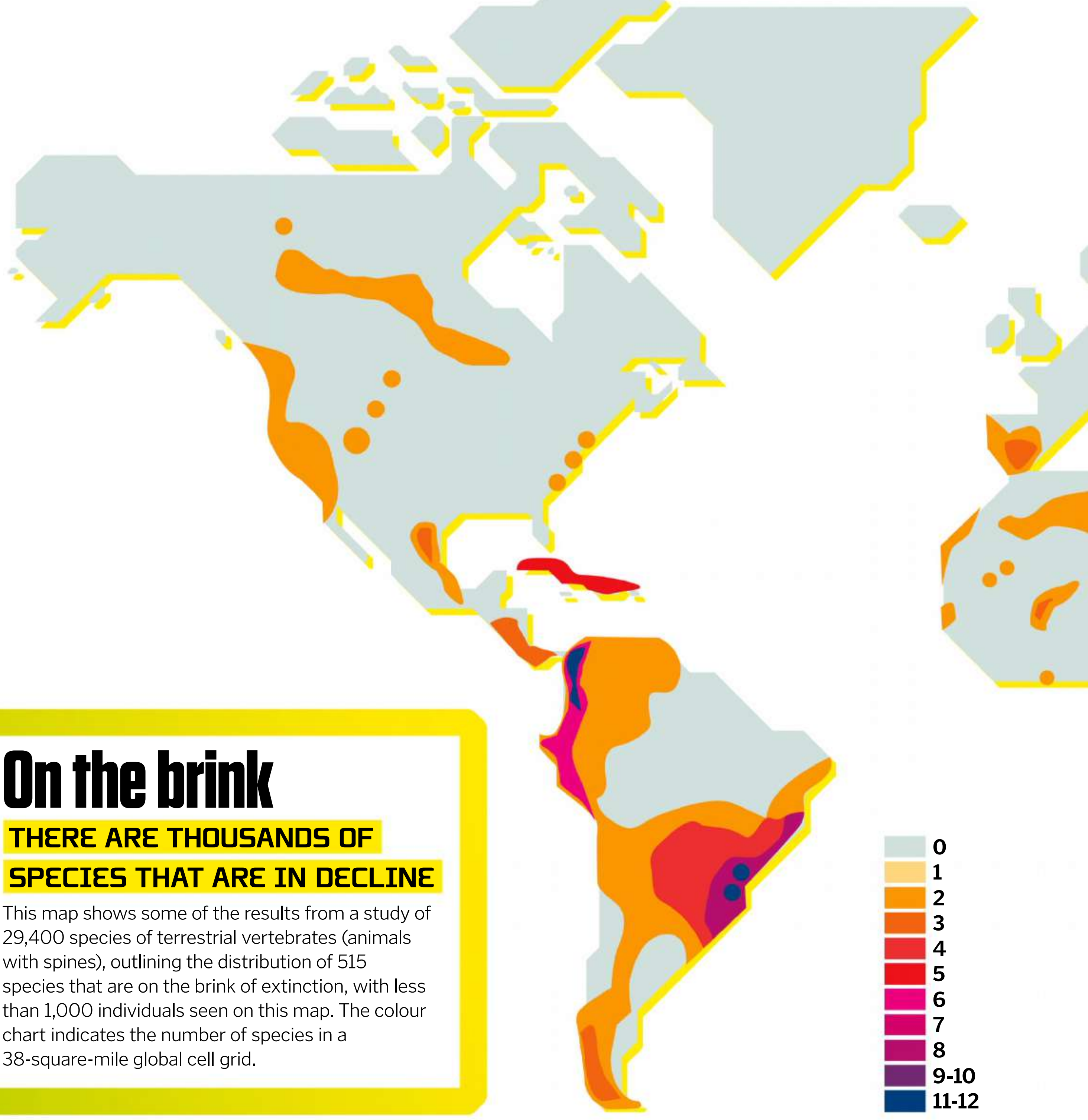
Humankind is always at the end of a pointed finger when it comes to casting blame for the climate crisis. Ever since the pollutant-pumping industrial revolution in 1760, humans have been the main contributor to Earth's current environmental crisis. From greenhouse gas emissions and ozone depletion, to deforestation, the plastic pile-up and the illegal animal trade, we have actively stripped the world of some species, and threatened many more.

There are those that argue climate change and the extinction of animal species are a natural part of life, and in some ways that's true. After all, the first five mass extinctions occurred

On the brink

THERE ARE THOUSANDS OF SPECIES THAT ARE IN DECLINE

This map shows some of the results from a study of 29,400 species of terrestrial vertebrates (animals with spines), outlining the distribution of 515 species that are on the brink of extinction, with less than 1,000 individuals seen on this map. The colour chart indicates the number of species in a 38-square-mile global cell grid.



DID YOU KNOW? *Since 1500, Earth has lost around one species of land vertebrate every two years*

without the presence of people. However, the difference is the speed at which these mass extinctions happen.

Fossil records don't just tell us what creatures existed before us, but also how long a species can naturally survive before becoming extinct, without human interference. This is referred to as the background rate, which is set at around a million years. Currently, because of human activity, this background rate is tens of thousands of times higher, meaning species are becoming extinct much faster than they should be. Studies have found that some species lost from Earth would have continued to survive for 800 to 10,000 years without the interference of human activities.

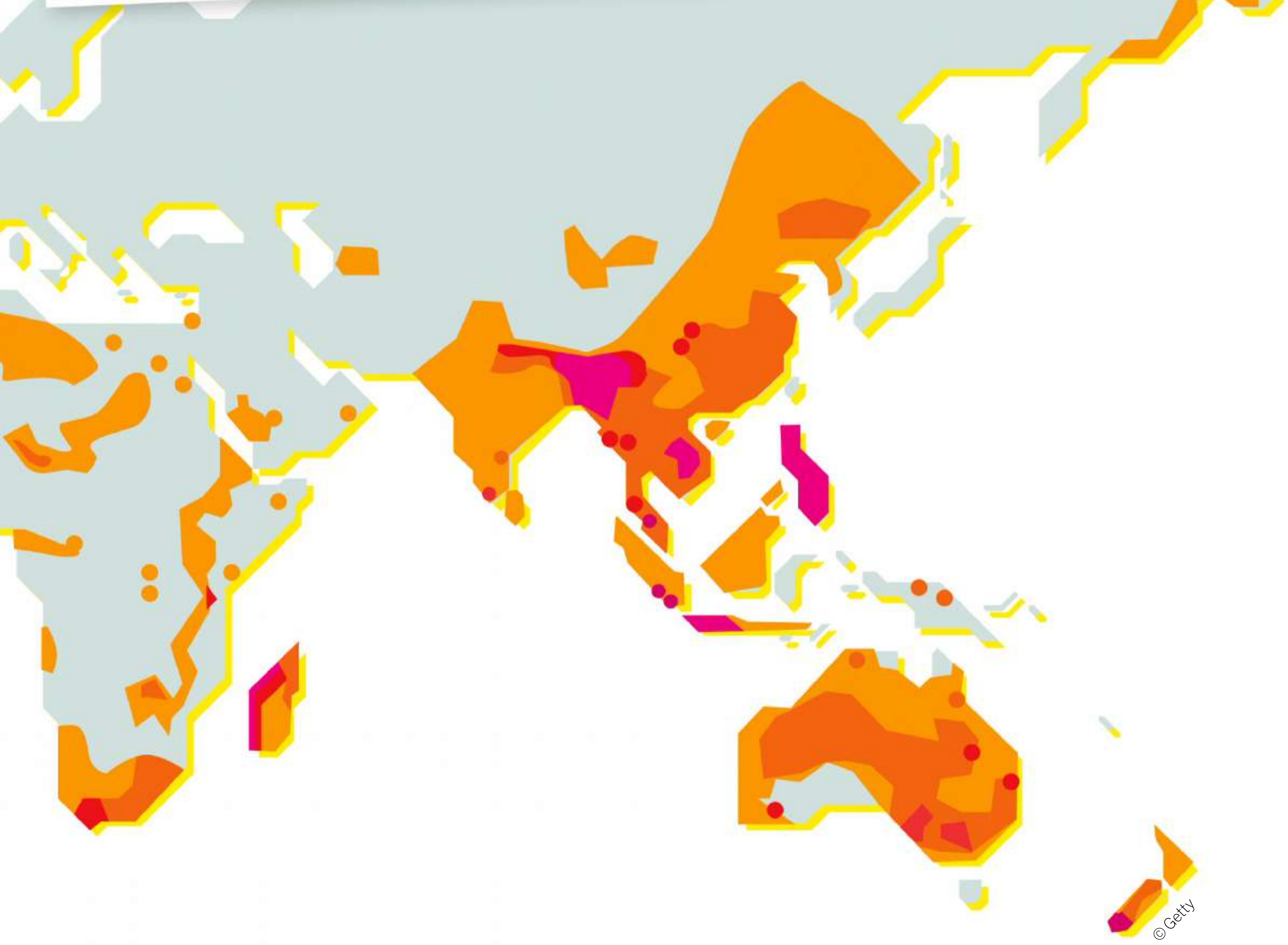
PANDEMIC PERSPECTIVE

Never before has the world been able – if not forced – to take a step for normal life and give nature the breathing room it needs. 2020's lockdowns have led to a 17 per cent global decrease in carbon emissions, and a 20 per cent fall in nitrogen oxide levels. Waterways cleared up and animals were seen venturing into cities and towns around the world. While it appears a wonderful revival for the planet, it's a temporary one as human civilisation returns to normal and extinctions return to their previous rate.

Ecotourism is an industry that fuels conservation efforts worldwide, and since global travel restrictions were imposed, it's on the verge of collapse. Without the income of tourists, conservationists aren't able to help protect vulnerable species from poaching, which during the pandemic has been on the rise. Rhinos in Botswana, wild cats in South America and tigers in India have all been targeted over the last year.

Aerial view of deforestation in the Amazon caused by the growing demand for agricultural areas

© Getty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5 FACTS ABOUT ALMOST-EXTINCT SPECIES

1 Javan rhino There are only 74 wild individuals left in the world, which live on the Indonesian island of Java. These armoured giants once roamed throughout Asia and northeast India just 150 years ago.

© Alamy

2 Mountain gorillas Nesting in the dense forests of the Congo Basin, mountain gorilla numbers are currently just over 1,000. This is an increase compared to previous years, but habitat loss and hunting continues to threaten their existence.

© Getty

3 Asian elephant In just 75 years the population of Asian elephants has dropped by roughly 50 per cent, with around 50,000 remaining in the wild.

© Getty

4 Orangutan Around 100 years ago there were more than 230,000 of these orange apes swinging through the trees. Current estimates put wild Bornean populations at 104,700 and Sumatran numbers at only 14,000.

© Getty

5 Vaquita The rarest marine mammal, these little porpoises are on the verge of extinction, with just ten known individuals swimming through Mexico's Gulf of California. Vaquita are killed by illegal fishing in protected areas.

© Alamy

Lab-grown animals can diversify a gene pool

© Getty

Turning back the clock

HOW SCIENCE IS TRYING TO SLOW DOWN THE SIXTH MASS EXTINCTION

Humans might be the driving force behind this accelerated extinction event, but we are also the answer to stopping it. The world is awash with scientists, conservationists and environmentalists working in both the laboratory and in political battlegrounds to protect endangered species.

From tackling global pollution emissions in the 2016 Paris Agreement to the UK's Global Resource Initiative that combats deforestation, legislation will always be at the forefront of the fight against mass extinction. In particular, one of the biggest direct threats to endangered life is the illegal animal trade.

In wake of the current global pandemic, wildlife markets have been put into the spotlight as not only being environmentally irresponsible, but potentially dangerous to human health through zoonotic diseases – those that jump from animals to humans – such as COVID-19. These markets are found throughout the world and trade live exotic animals or products derived from them. For example, China's bear farms cage 20,000 Asiatic black bears for their bile, resulting in the wild population declining.

Lawmakers are tackling these kinds of markets with growing success. In Vietnam, for example, Prime Minister Nguyen Xuân Phúc signed a new directive that bans wildlife imports and closes illegal wildlife markets.

NEW EYES IN THE SKY

One of the best ways to help prevent species from becoming extinct is to monitor their populations and identify any problems before it's too late to help. Currently camera traps and surveys conducted on foot or from aircraft are the main method of data collection. However, recent research has used a combination of satellite imagery and artificial intelligence to observe animals from space. Using high-resolution aerial photographs of Africa's grasslands, researchers created an algorithm to sweep over thousands of miles and count every elephant pictured in the blink of an eye. The technology is still in its infancy and is limited to areas where large animals, such as elephants, aren't obscured by forest habitats.

SAVED BY CLONING

Another potential solution to combat extinction could be to clone species. In February 2021, scientists revealed they had successfully cloned a black-footed ferret, from an animal that had died more than 30 years ago. Native to North America, these small mammals were thought to be extinct until a small colony was found in the early 1980s, which were entered into a breeding program and reintroduced around America. Due to inbreeding, the population of around 650 ferrets is at risk of extinction once again. This inspired researchers to create a genetic copy from the preserved cell of a wild female, named Willa, who died in the 1980s. The process of cloning was similar to that used to clone Dolly the sheep back in the early 1990s. Scientists hope that after time spent in captivity, cloned members of the species can successfully re-enter the wild, offering a new conservation tool to protect endangered species.

It is legal, scientific and technological advances such as these that will help to conserve Earth's wildlife and hopefully slow down the sixth mass extinction.

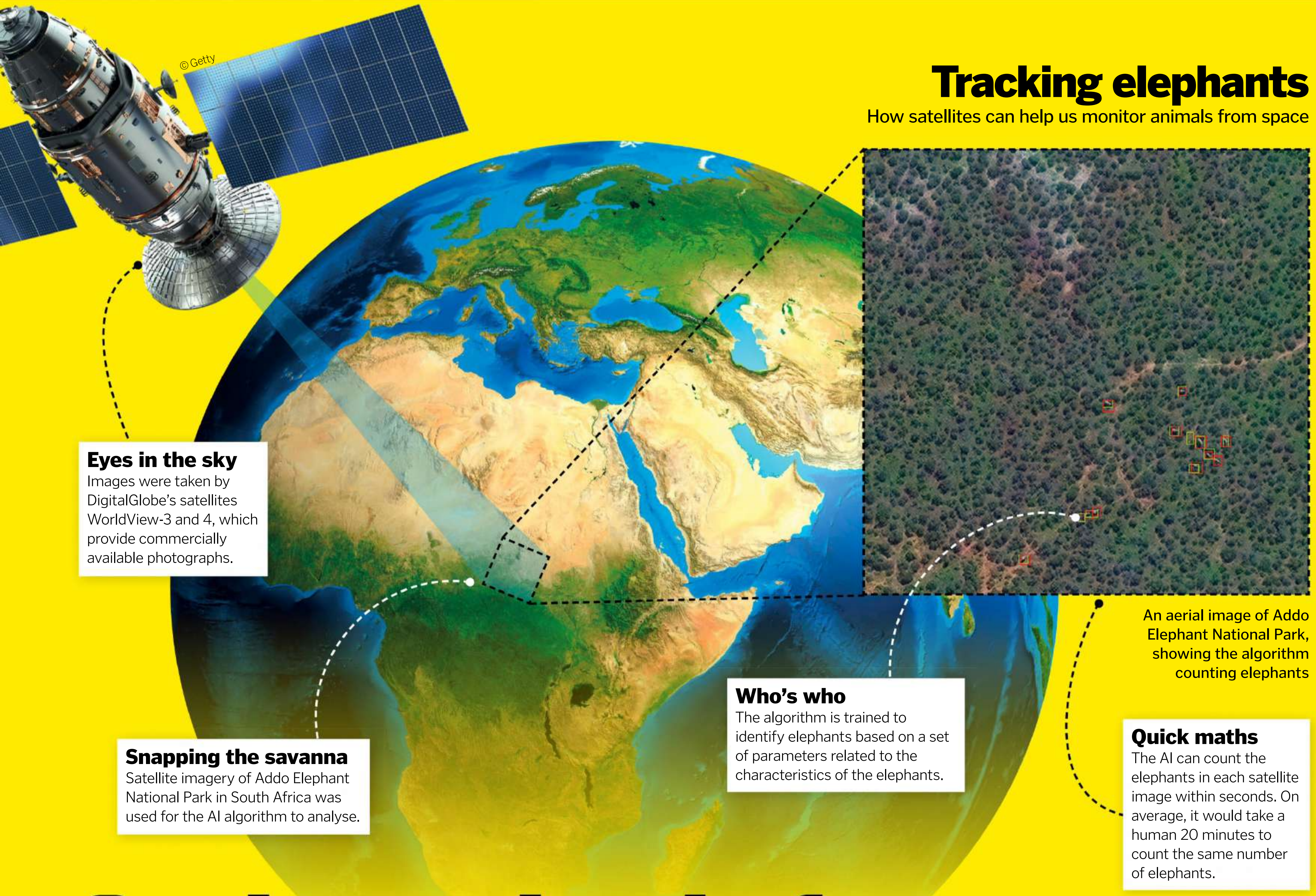
The first cloned black-footed ferret, called Elizabeth Ann

© USFWS National Black-footed Ferret Conservation Center

DID YOU KNOW? *Through conservation efforts, up to 48 bird and mammal species have been saved from extinction since 1993*

Tracking elephants

How satellites can help us monitor animals from space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Eyes in the sky
Images were taken by DigitalGlobe's satellites WorldView-3 and 4, which provide commercially available photographs.

Snapping the savanna
Satellite imagery of Addo Elephant National Park in South Africa was used for the AI algorithm to analyse.

Who's who
The algorithm is trained to identify elephants based on a set of parameters related to the characteristics of the elephants.

An aerial image of Addo Elephant National Park, showing the algorithm counting elephants

© Maxar Technology

Quick maths
The AI can count the elephants in each satellite image within seconds. On average, it would take a human 20 minutes to count the same number of elephants.

Saving animals from space

DR OLGA ISUPOVA, CREATOR OF THE ELEPHANT-TRACKING AI, TELLS US HOW THIS TECHNOLOGY COULD BE USED IN THE FUTURE

© Dr Olga Isupova

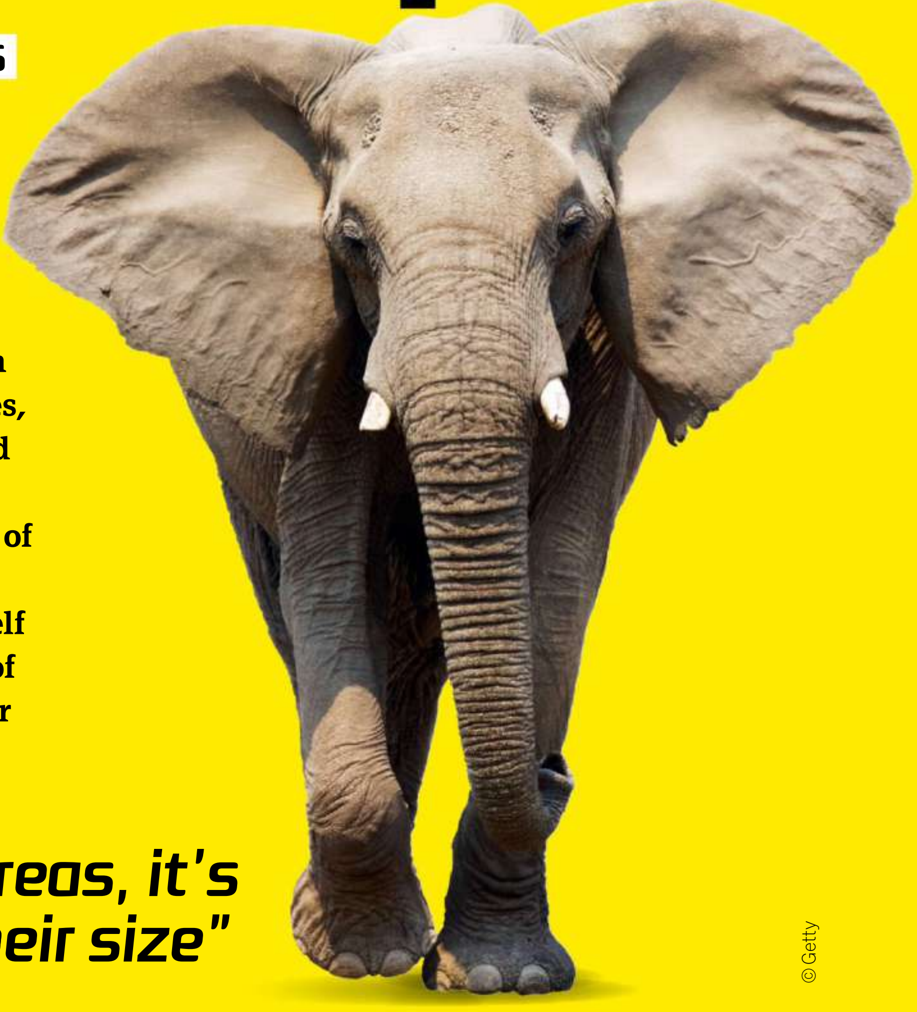
CAN THE AI BE APPLIED TO DIFFERENT SPECIES?

Yes. We are currently looking to get a hold of data to test the same approach on rhinos. The main question here would be the size of the animals and their habitats. We can't see through clouds, obviously, but also we can't see through forested areas. Therefore we can't look for animals that are in dense forest. If they're in open areas, then it's just a question of their size.

IS THE AI COMPLETELY LIMITED BY ANIMAL SIZE, OR COULD IT POTENTIALLY BE ADAPTED TO SPOT SMALLER SPECIES?

It depends on the resolution of the satellite, and it also depends on the machine learning algorithm performance. We are currently looking at how we can improve the algorithm itself to look specifically for smaller objects. We could also look for those animals who appear in herds. For example, with penguin colonies, the model can detect the whole colony and then have an additional algorithm that approximates the count based on the size of the colony. Also, you can look for the footprints of the animals. The animal itself can be quite small, but if there are many of them and they leave lots of footprints after them, we can also try to track that.

> *"If they're in open areas, it's just a question of their size"*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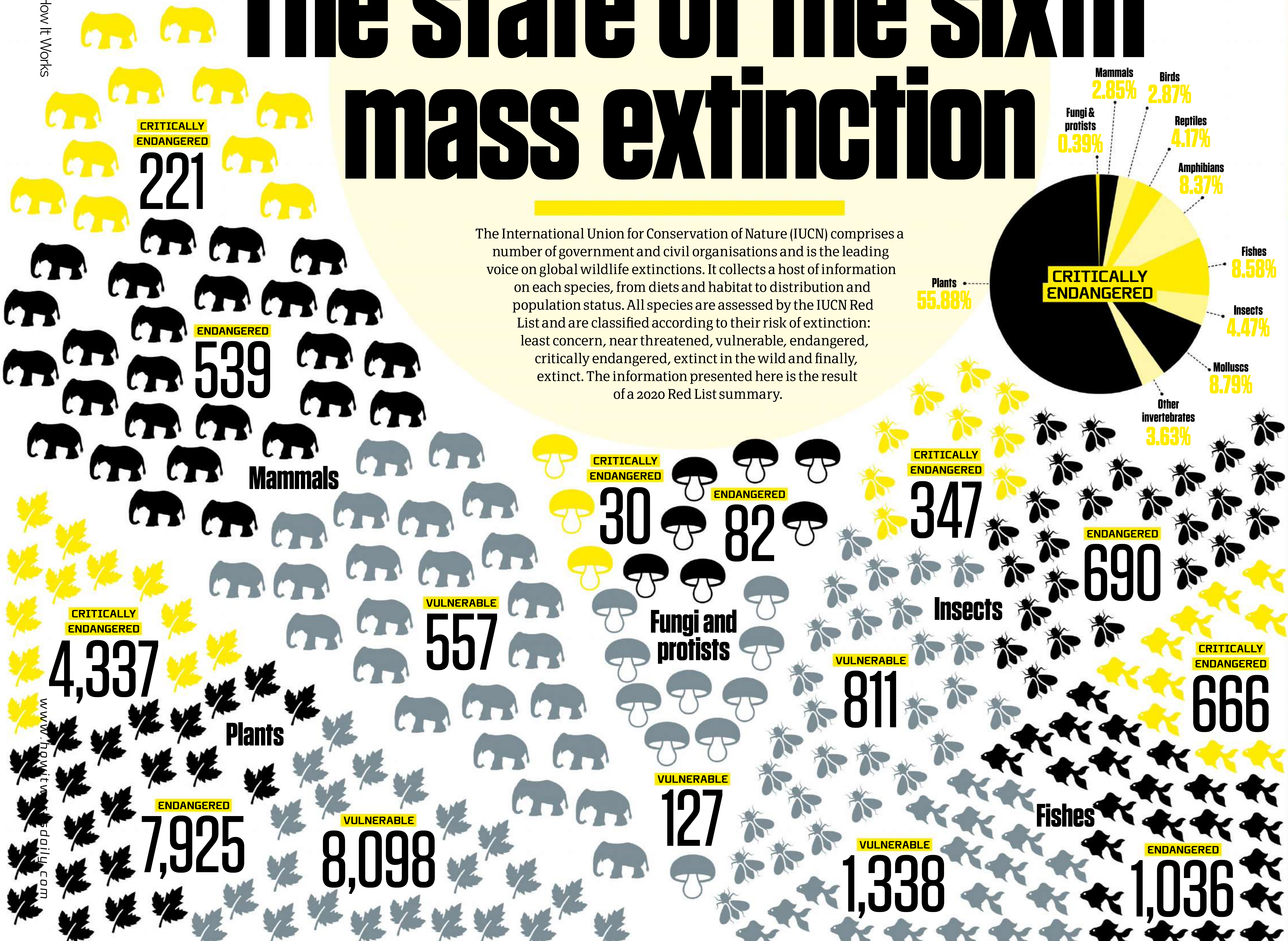
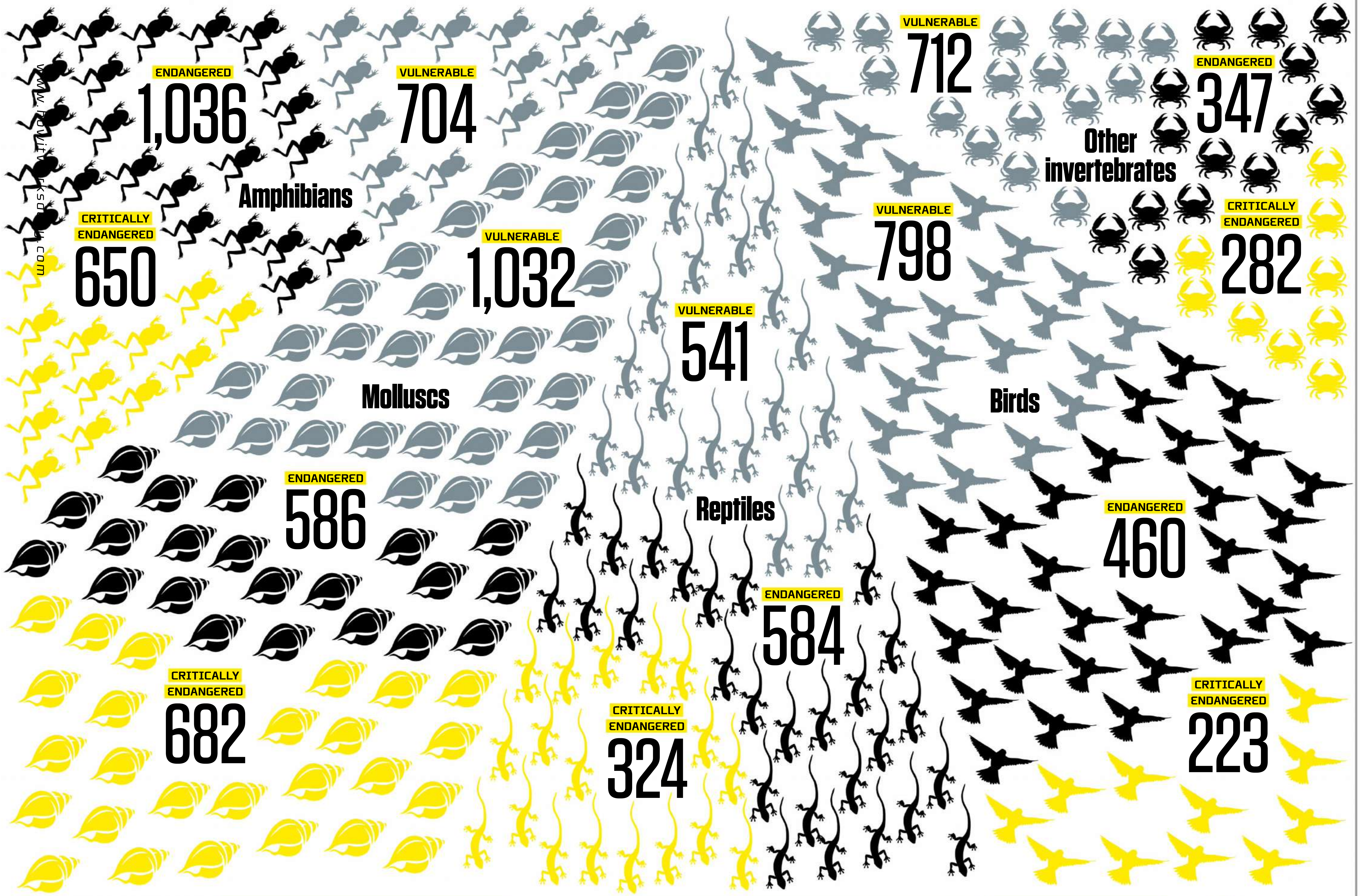
The state of the sixth mass extinction

The International Union for Conservation of Nature (IUCN) comprises a number of government and civil organisations and is the leading voice on global wildlife extinctions. It collects a host of information on each species, from diets and habitat to distribution and population status. All species are assessed by the IUCN Red List and are classified according to their risk of extinction: least concern, near threatened, vulnerable, endangered, critically endangered, extinct in the wild and finally, extinct. The information presented here is the result of a 2020 Red List summary.



DID YOU KNOW? *The last male northern white rhino died in 2018 – only two living females remain*



IUCN assessed species
81%

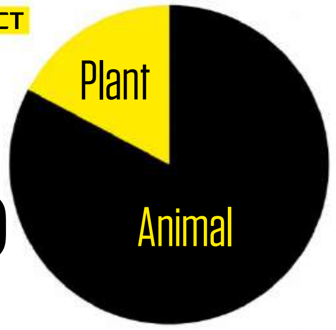
IUCN ASSESSED SPECIES
Current: **128,918**
Goal: **160,000**

Totals

CRITICALLY ENDANGERED
7,762
ENDANGERED
13,285
VULNERABLE
14,718

TOTAL
- 35,765 species are threatened with extinction
- That's 28 per cent of all species assessed

NUMBER OF SPECIES EXTINCT
982
Animal: **817 (83%)**
Plant: **165 (17%)**



AMAZINGLY WEIRD AUSSIE ANIMALS

Meet some of the world's strangest species from down under

Words by **Scott Dutfield**

Australia is famed for its weird and wonderful animals. From the alien blue-ringed octopus, which carries enough venom to kill 26 adult humans within minutes, to the patchwork anatomy of the duck-billed platypus, Australia is packed with species that, to the rest of the world, don't make a lot of sense.

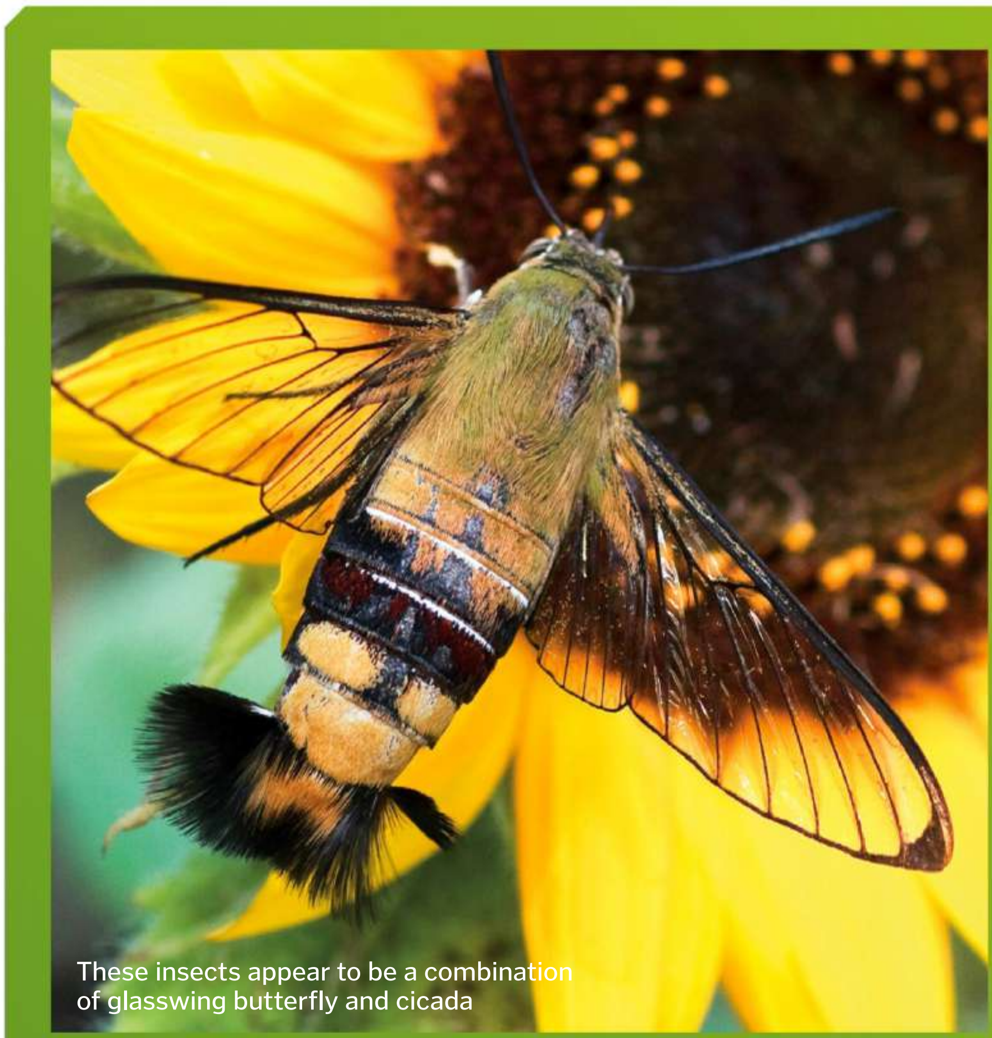
This is because these strange species often aren't found anywhere else on Earth. 87 per cent of Australia's mammals, 93 per cent of its reptiles and 45 per cent of its bird species can only be found in Australia. During Earth's geographical evolution the smallest of the seven continents, modern-day Australia, broke away from a supercontinent that dominated the landscape of the world hundreds of millions of years ago. This meant that the species living in Australia didn't evolve in quite the same way as animals elsewhere on Earth, with the exception of migrating species that could fly or swim beyond the shores of Australia. This has resulted in some of the most fascinating, frightening and downright odd animals to ever walk the Earth.

Ocean sunfish *[Mola mola]*

Although not endemic to Australia, these strange creatures can be seen swimming around the southern shores of the continent. Sunfish are the heaviest known bony fish on Earth, with one species, *Mola alexandrini*, reaching a whopping 2,300 kilograms in weight. What's most notable about these fish are their incredibly large dorsal and anal fins, making them over four metres tall. These ocean giants deep dive into very cold waters to feed on zooplankton and avoid predators. To warm themselves back up they move close to the surface to bask in the Sun's heat.

Unfortunately sunfish numbers are in decline, and they're now classed as vulnerable by the International Union for Conservation of Nature (IUCN)

© Getty



These insects appear to be a combination of glasswing butterfly and cicada

© Getty

Pellucid hawk moth

[Cephonodes hylas]

These unusual moths can be found buzzing around flowers across Queensland. As the insect equivalent of a hummingbird, pellucid hawk moths fly using intricate transparent wings that beat at an incredible rate during flight. Typically the wings of a moth or butterfly have vibrant or patterned appendages that can be used for communication and camouflage. However, some scientists think that these transparent wings make the moths invisible to other animals. On a nanoscale, the moths' wings are made up of an array of protrusions similar to the structure of an insect eye. This prevents light from being reflected and causing any shine during flight, making them invisible to potential predators.

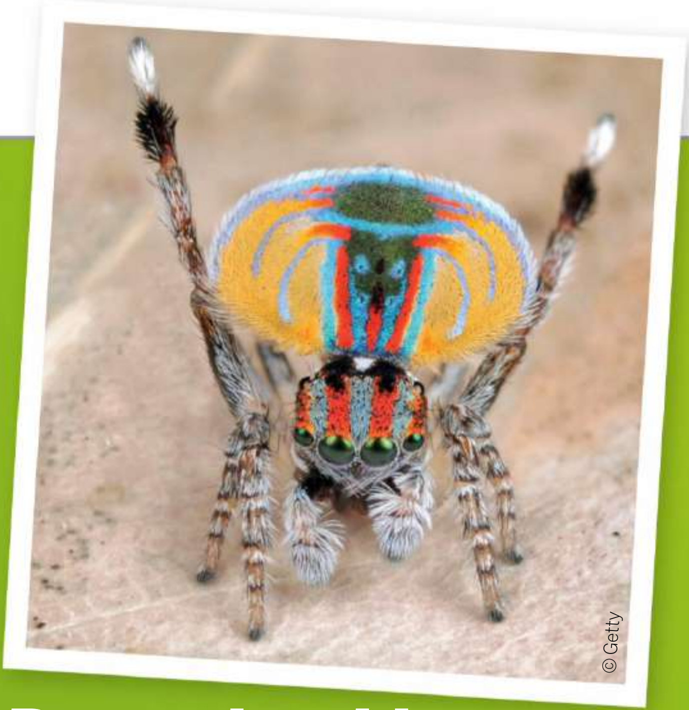
Giant centipedes can be found throughout Australia, from its tropical rainforests to its deserts

© Alamy

Giant centipede

[Ethmostigmus rubripes]

Over 16 centimetres long and made up of 27 body segments supporting up to 23 pairs of legs, Australia's giant centipede is one of the biggest in the world. To sustain their body size, these arthropods feed on other insects, snails and worms. To capture and kill their prey, the centipedes have modified legs called forcipules that curve around the head and can deliver a potent venom. The venom is strong enough to kill a large animal quickly, and can cause severe pain to humans if the insect is disturbed or handled.



© Getty

Peacock spider

[Maratus volans]

The peacock spider is found in the south of Australia and is well known for its elaborate courtship dance. Males will wave around their third pair of legs and reveal their vibrant abdomen to attract a female.

Net-casting spider

[Deinopis ravidus]

Australia is famous for its many scary spiders, but this species is one of the most innovative. Rather than building a silken web and passively waiting for prey to become entangled, this spider takes a proactive approach, using a net of silk to trap its food. These spiders typically use their nets to capture ants, beetles and even other spiders during the night. To help them see in the dark, these unusual arachnids have two large eyes, earning them the nickname of 'ogre-faced spider'. Before the Sun rises, net-casters will consume their nightly catch, including the net to recycle the silk.

Net-casting spiders are spread across Australia, from garden shrubs to forest trees

© Alamy

© Alamy

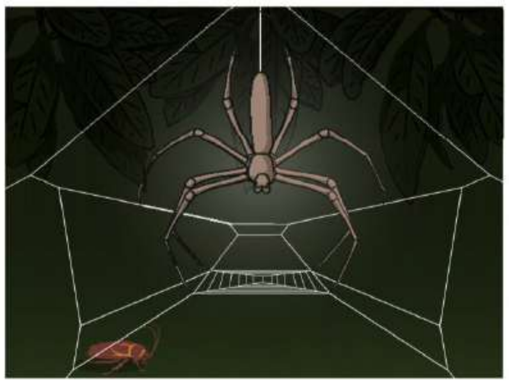
Giant fishkiller

[Lethocerus insulanus]

As the name suggests, these aggressive-looking water bugs have a taste for small fish, along with tadpoles, frogs and snails. To catch their prey, they submerge themselves on a plant stem, grabbing passing fish using their long, needle-tipped front legs. They then inject digestive enzymes into the prey's body to liquefy tissues, making it ready for consumption.

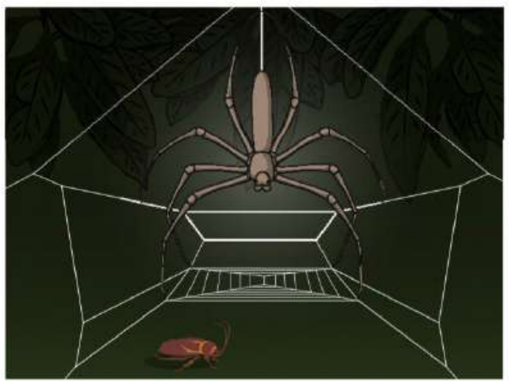
Night fishing

How these prolific predators snag their prey



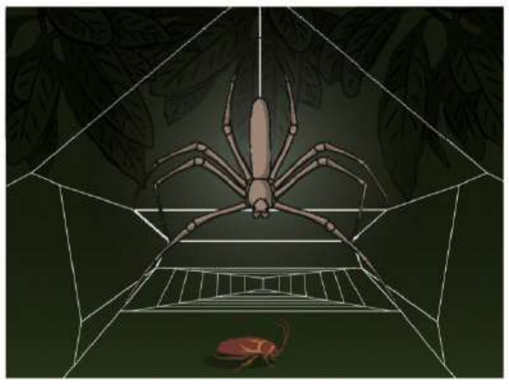
1 Net tension

While the spider is holding the net, it is relaxed. When the net is extended the accumulated tension snaps it back around the prey upon release.



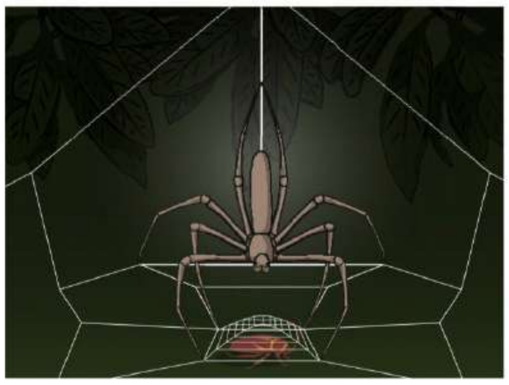
2 Holding steady

The spider holds the net in its first pair of legs, hanging down from a safety line by its last pair. This is the position it will maintain until potential prey passes by.



3 Widen cast

Once the prey is in sight, the spider will drop down the safety line, widening the net to cast it over the unsuspecting insect that's about to become a tasty meal.



4 Capture

The unfortunate prey is enclosed within the net, which is then reeled in and tied up with more silk, ready for the contents to be eaten later on.

Illustrations by © Ed Crooks

© Alamy

Giant panda snail

[Hedleyella falconeri]

Named after its long pair of black stalks, the giant panda snail is a Goliath in the mollusc world, with its shell reaching ten centimetres long. They spend their time in the subtropical rainforest feeding on fungi on the forest floor after or during rainfall.

© Alamy

Spiny leaf insect

[Extatosoma tiaratum]

Masters of camouflage, these insects have evolved an exoskeleton that mimics the foliage of their forest habitat. They've also been found to sway in the wind to mimic the movement of vegetation. They curl up their abdomen to look like a scorpion.

© Alamy

Arafura filesnake

[Acrochordus arafurae]

These stealthy serpents spend their time swimming through the waters of lagoons, pools and flooded grasslands. Arafura filesnakes feed almost exclusively on fish and can spend hours at a time under the water hunting. To immobilise their prey, they wrap around and constrict fish up to one kilogram before ingesting them.

Short-beaked echidna

[Tachyglossus aculeatus]

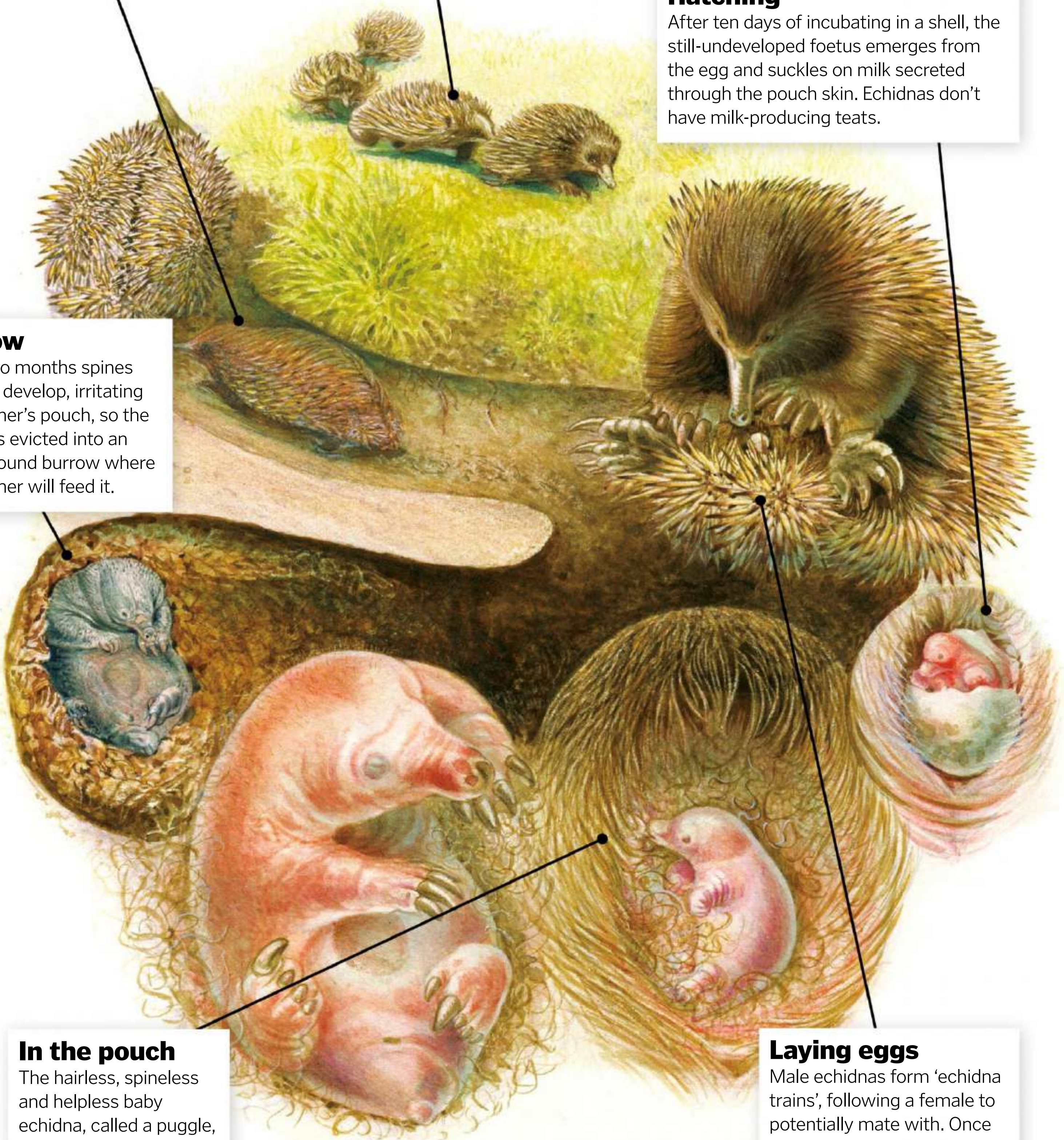
Echidnas are named after a creature in Greek mythology referred to as the 'mother of monsters'

© Getty

Echidnas are not only one of the strangest animals in Australia, but possibly the entire world. These hedgehog-like creatures are one of only two kinds of mammals on Earth that lay eggs – the other is the duck-billed platypus. Adding to their oddities, echidnas have toothless jaws, so they crush their insect prey, of which they eat around 40,000 per day, between their tongue and the roof of their mouths. Echidnas feed during the night to avoid the high daytime temperatures and to maintain their low body temperature of 32 degrees Celsius.

Hatching mammal eggs

From shell to spines, how echidna become adults



Juvenile
Echidnas are weaned at around six months old, weighing around two kilograms, and will leave the burrow.

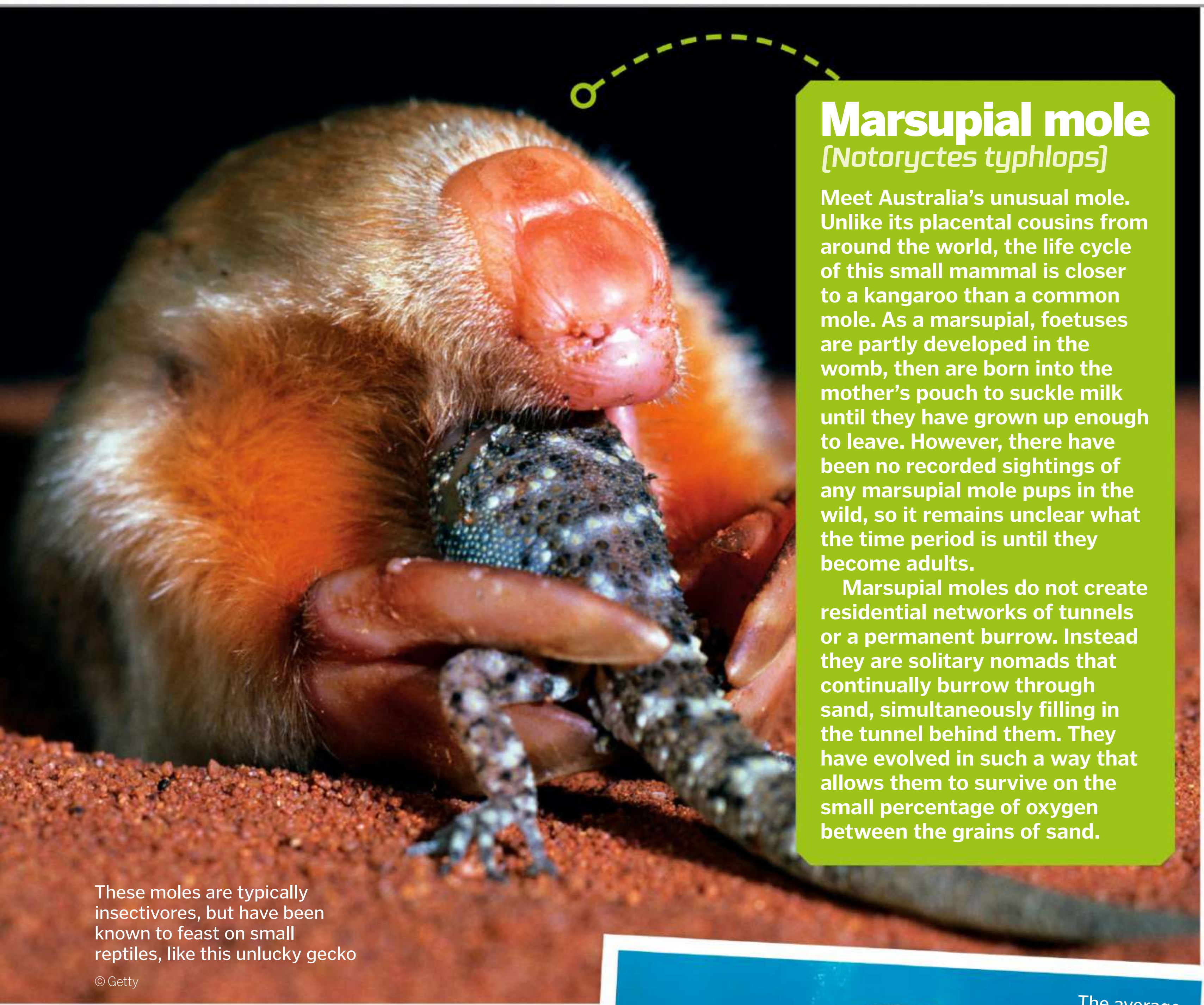
Adulthood
Echidnas reach sexual maturity between five and 12 years old.

Hatching
After ten days of incubating in a shell, the still-undeveloped foetus emerges from the egg and suckles on milk secreted through the pouch skin. Echidnas don't have milk-producing teats.

Burrow
After two months spines begin to develop, irritating the mother's pouch, so the puggle is evicted into an underground burrow where the mother will feed it.

In the pouch
The hairless, spineless and helpless baby echidna, called a puggle, will continue to feed on fatty milk for another month in the pouch.

Laying eggs
Male echidnas form 'echidna trains', following a female to potentially mate with. Once they have mated, a female will lay an egg in her pouch after around 24 days.



These moles are typically insectivores, but have been known to feast on small reptiles, like this unlucky gecko

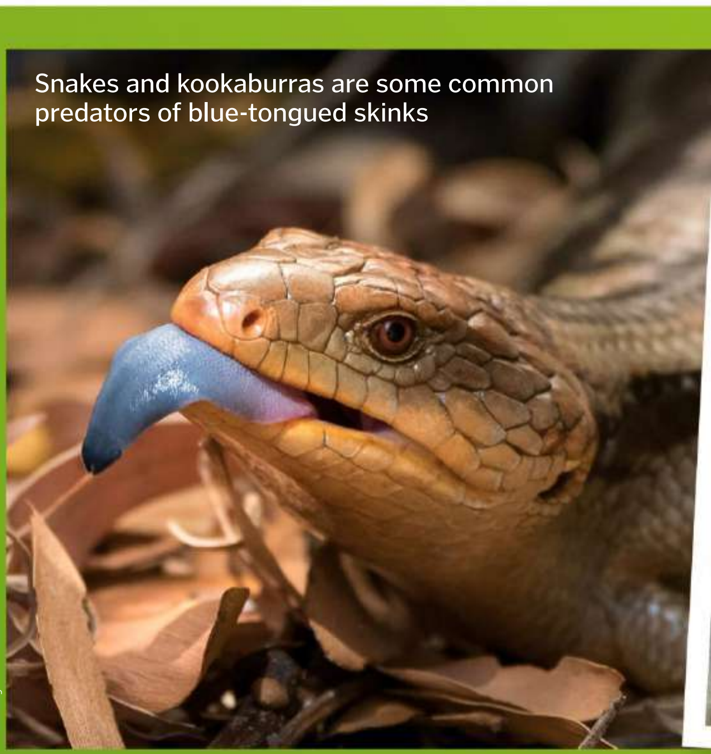
© Getty

Marsupial mole

[Notoryctes typhlops]

Meet Australia's unusual mole. Unlike its placental cousins from around the world, the life cycle of this small mammal is closer to a kangaroo than a common mole. As a marsupial, foetuses are partly developed in the womb, then are born into the mother's pouch to suckle milk until they have grown up enough to leave. However, there have been no recorded sightings of any marsupial mole pups in the wild, so it remains unclear what the time period is until they become adults.

Marsupial moles do not create residential networks of tunnels or a permanent burrow. Instead they are solitary nomads that continually burrow through sand, simultaneously filling in the tunnel behind them. They have evolved in such a way that allows them to survive on the small percentage of oxygen between the grains of sand.



Snakes and kookaburras are some common predators of blue-tongued skinks

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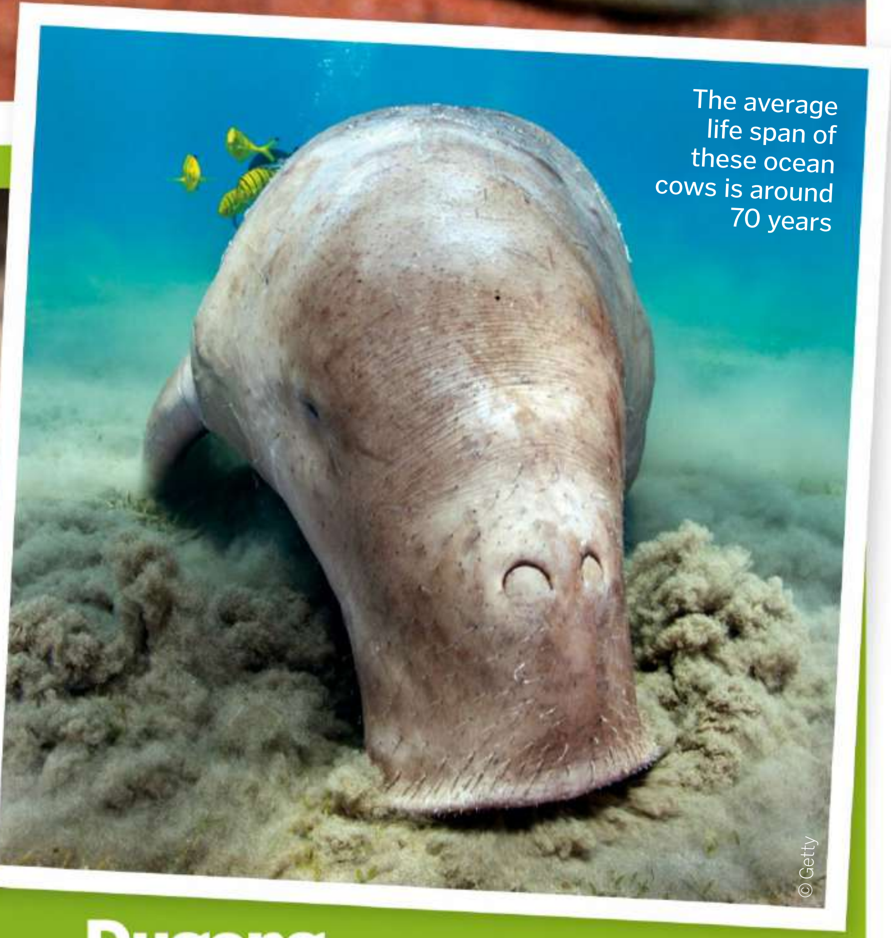


The average life span of these ocean cows is around 70 years

© Getty

Blue-tongued skink

[Tiliqua scincoides]

Found roaming through tussock grass and forest leaf litter, at around 60 centimetres long, this lengthy lizard is famous for sticking out its blue tongue. Skinks use their brightly coloured tongues to ward off predators, flattening them and puffing out their bodies to appear larger and more threatening. It's been found that the front of the tongue reflects ultraviolet (UV) light. This suggests that common predators of the skink, such as bird species that can see UV rays, will be dazed by a flash of UV and think twice about attacking them.

Dugong

[Dugong dugon]

Often referred to as 'sea cows', these marine mammals spend most of their time hoovering up seagrass from shallow coastal waters. Unlike their manatee cousins, dugongs do not live in freshwater and sport a dolphin-like tail. They can be found mostly in the northern and western Australian waters. Dugongs can weigh over 360 kilograms, consuming up to 40 kilograms of seagrass every day. These mammals are equipped with a rounded muscular lip, called a cleft, that rips up the seagrass from the seabed.

5 FACTS ABOUT

BIZARRE BIRDS

1 Bush stone-curlew These thick-kneed birds are known for their high-pitched calls that sound like a bone-chilling scream. It's often hard to spot where the screams are coming from because their plumage also makes them blend in among leaf litter.

2 Lyrebird The master of vocal mimicry, this amazing bird is capable of copying the calls of 20 different bird species. Some have even been found to mimic other sounds such as chainsaws and car alarms.

3 Cassowary These dinosaur-looking flightless birds have evolved a helmet, or 'casque', on top of their heads, made from a spongy material and covered in keratin. Scientists still don't really know for sure why they have them.

4 Laughing kookaburra As the name suggests, these birds are best known for their bird call, which sounds like a maniacal chuckle. They usually call during early dawn and at dusk, which earned them the nickname of 'bushman's clock'.

5 Tawny frogmouth Blending seamlessly with tree bark, these cryptic creatures are known more for their wide mouths than their feathers. It allows them to prey on small mammals as well as reptiles, frogs and other birds.

5 x © Getty

Inside a rattlesnake's rattle

What gives these reptiles their distinguishing sound?

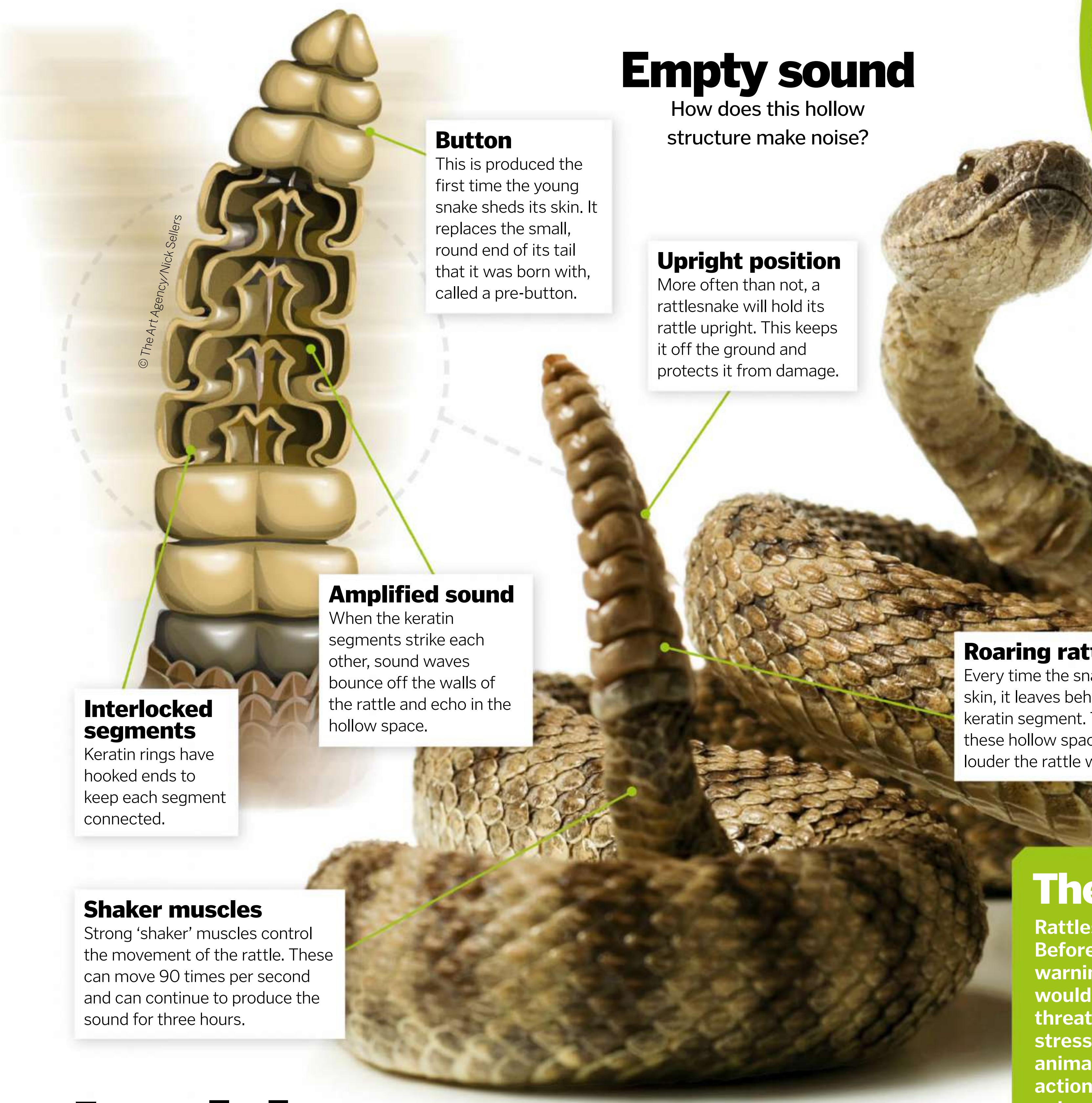
Found in a wide range of habitats across North and South America, rattlesnakes add a vibratory rattling sound to the landscape. From afar this might sound relaxing, almost meditative, but it often indicates that you're approaching danger. The rattlesnake shakes its rattle to warn off any animal it deems a threat, and it considers humans among these threats. When hunting for rodents and other food, the snakes can also use this rattle to distract animals before pouncing on them and making them their dinner.

Beyond its clattering chorus, this species of snake is equipped with toxic venom. However, rattlesnakes aren't usually fatal to humans. If you are unfortunate enough to suffer a bite, your symptoms would include pain and swelling,but you might not need hospital treatement. Most of the time rattlesnakes won't even release their venom when biting a human. This is because they don't bite us with the aim of killing and eating us, but do it to scare us away.

These sounds are a good indication of their presence, but it is a misconception that all rattlesnakes make this noise. Young snakes, for example, have an underdeveloped rattle that lacks the two segments required to produce a noise. And while it might sound and look like a maraca being shaken, there are no loose objects inside the rattle to create this noise.

Empty sound

How does this hollow structure make noise?



© The Art Agency/Nick Sellers

© Getty

Button
This is produced the first time the young snake sheds its skin. It replaces the small, round end of its tail that it was born with, called a pre-button.

Upright position
More often than not, a rattlesnake will hold its rattle upright. This keeps it off the ground and protects it from damage.

Amplified sound
When the keratin segments strike each other, sound waves bounce off the walls of the rattle and echo in the hollow space.

Roaring rattles
Every time the snake sheds its skin, it leaves behind a new keratin segment. The more of these hollow spaces, the louder the rattle will be.

Interlocked segments
Keratin rings have hooked ends to keep each segment connected.

Shaker muscles
Strong 'shaker' muscles control the movement of the rattle. These can move 90 times per second and can continue to produce the sound for three hours.

© Getty

Rattlesnakes can sense heat coming from their prey before they attack

The silent shake

Rattlesnakes didn't always have rattles. Before developing their characteristic warning signal, scientists believe they would still shake their tails when threatened. Whether this was a sign of stress or an attempt to scare away other animals with the movement alone, the action worked in letting threatening animals know that the snake was about to attack. How the rattle evolved is less well known, but some think that a genetic mutation meant some snakes were more likely to leave excess skin behind at the end of their tails during shedding. As they continued to shake their tails, the outcome was a noisy deterrent to other species. Over time this advantage kept the noisier snakes alive. These rattles would then have evolved further to become the more intricate and impressive structures they are today.

© Getty

Scan here to hear the high-pitched rattle these snakes have evolved to produce

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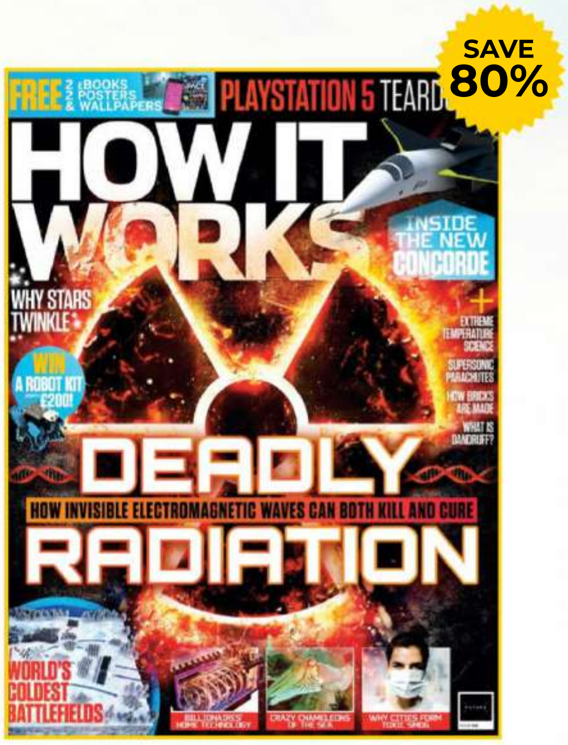
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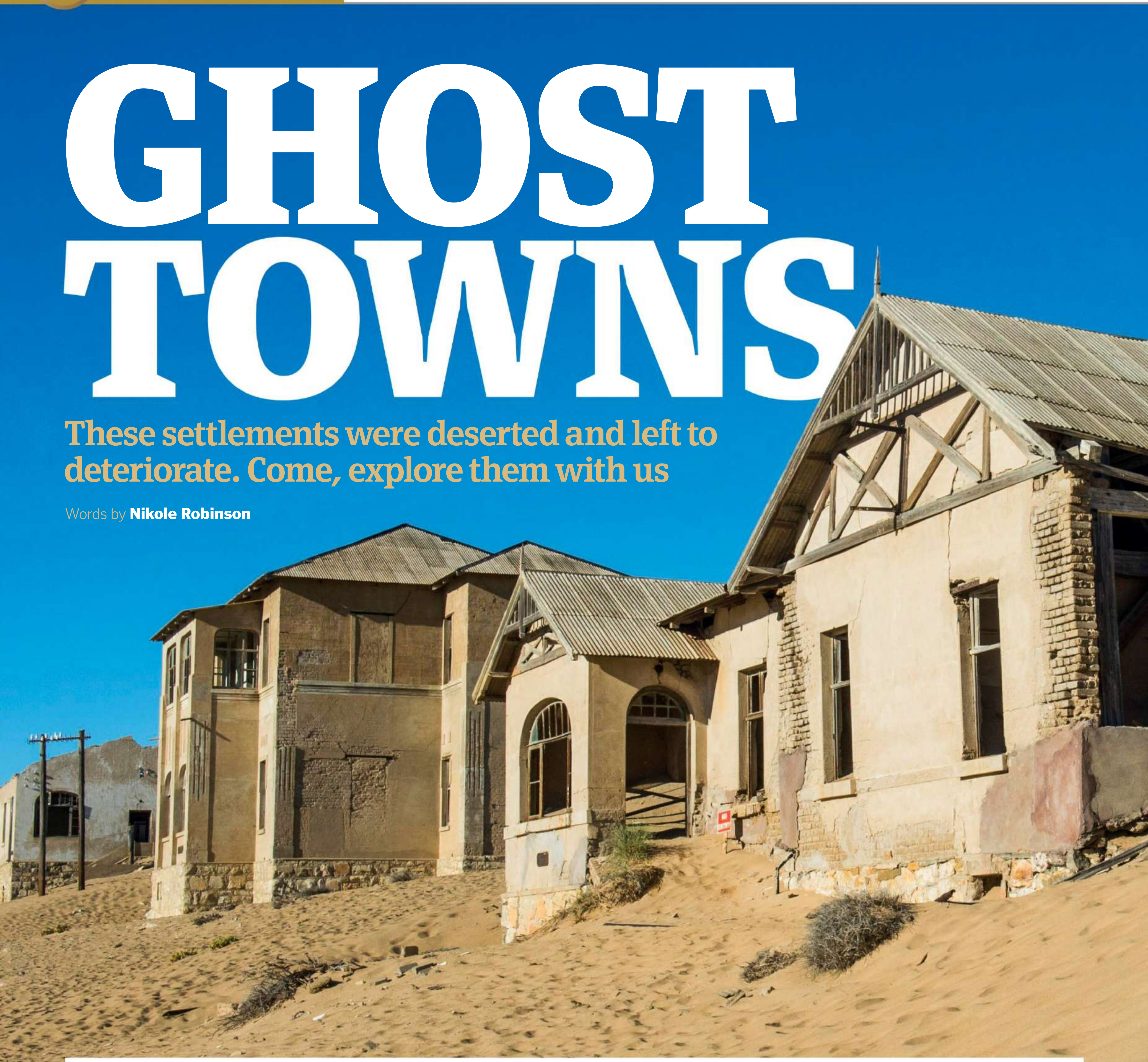
GHOST TOWNS

These settlements were deserted and left to deteriorate. Come, explore them with us

Words by **Nikole Robinson**



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There's something incredibly eerie about a town with no inhabitants, but there are many such places dotted around the world, left behind by those who once called them home. With no one remaining to maintain houses, buildings and roads, they slowly degrade over time, until one day rusted ruins and old stone structures are the only clues that humans once thrived there.

There are many reasons for an entire population to abandon a once-prosperous town, with floods, earthquakes, droughts or war driving people away for their own safety. Though both natural and human-made disasters can make an area uninhabitable, some settlements are left behind by choice when resources run out or the economy begins to collapse. Many of the world's ghost towns started out as mining communities, but once the ground stopped providing, there was nothing left to sustain them. Others were forsaken when the construction of a new road or railway bypassed the town, with people relocating to more accessible areas.

While many places are simply left to rot away, some of these neglected locations get a new lease of life as tourist attractions, acting as town-sized time capsules frozen at the point at which the occupants moved on. Those fleeing from disaster would often need to do so in a rush, so some buildings remain fully furnished, as if the people could come back at any moment.

DID YOU KNOW? *The control room of Chernobyl's reactor 4 can provide a fatal dose of radiation in just over a minute*

Reasons for abandonment

Natural disaster
Unpredictable events such as floods, earthquakes, volcanic eruptions, droughts or coastal erosion can make an area unsafe to live in.

War
When people's homes become part of a warzone, the inhabitants need to flee to avoid being killed or injured.

Resources
If food or water is scarce, there's no way for a population to survive, while mining towns need to be prosperous to support people.

Economy
Inhabitants are likely to relocate if the local economy is in trouble, or if there are no jobs in an area.

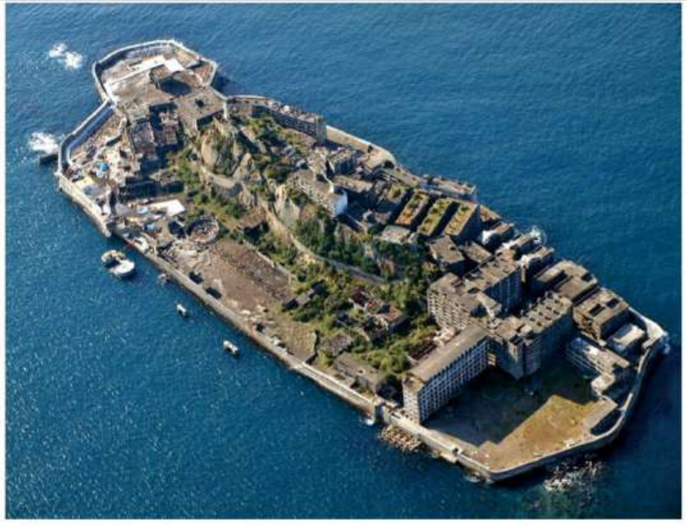
Radiation
Humans can get sick or die when exposed to large doses of radiation, so it's not safe to live near a source.

4x © Getty

Hashima Island

Location: Japan
Abandoned: 1974

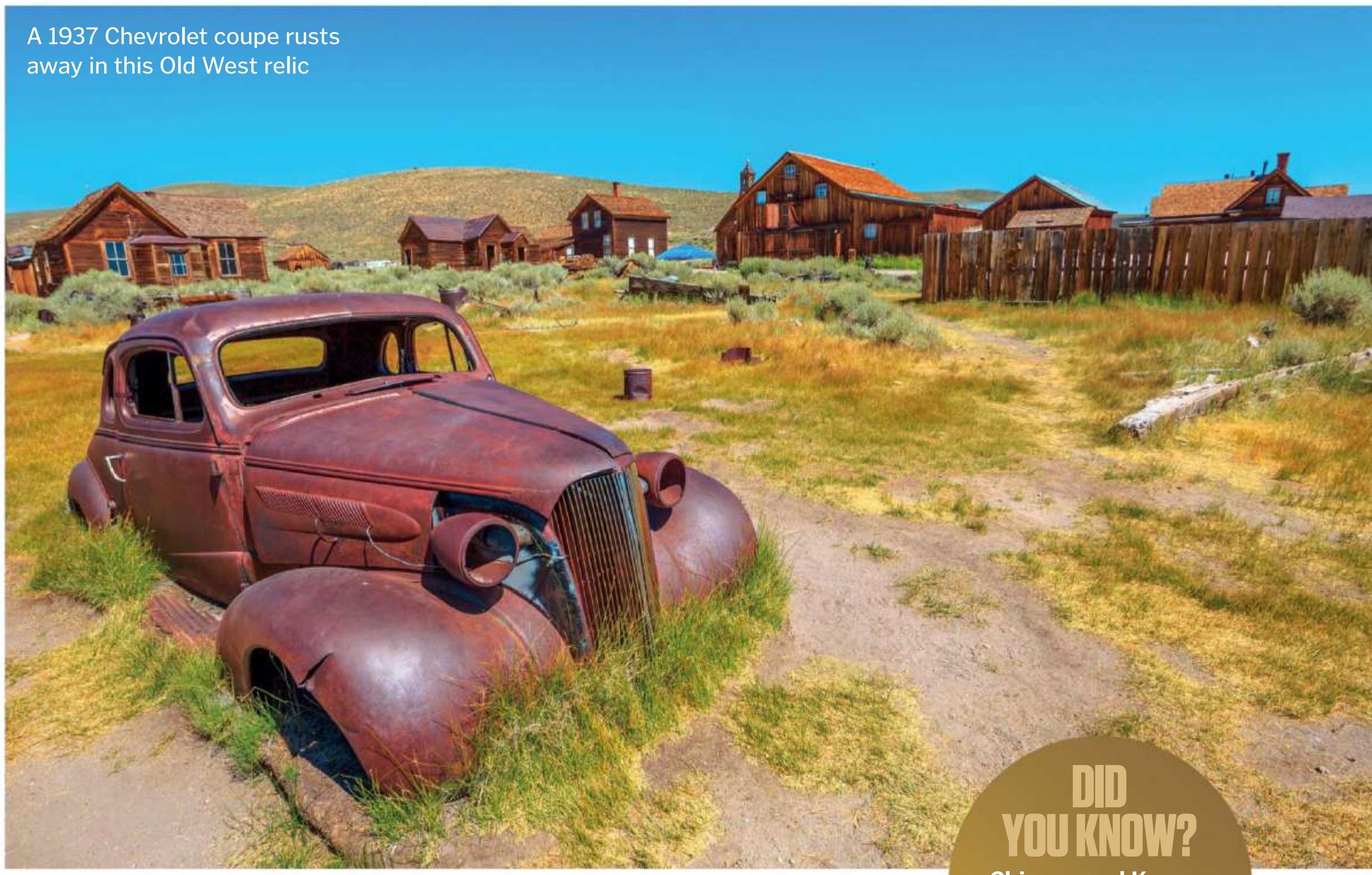
This 16-acre island lies deserted off the coast of Nagasaki, Japan, with the concrete buildings and sea wall a stark contrast against the ocean. As Japan began to rapidly industrialise in the mid-19th century, the island was opened as an undersea coal mine. Bought by Mitsubishi, the company reclaimed more land from the sea and built tall, sturdy, grey buildings to house coal miners and their families. The island's population peaked at 5,259 in 1959, but soon Japan began to rely on petroleum for fuel instead, making coal redundant. The mine was closed in January 1974, and all inhabitants had abandoned the island by April. In 2009 the island was reopened to tourists, with boat tours ferrying people from the mainland to take in the untouched concrete buildings and former coal mine, which was declared a UNESCO World Heritage Site in 2015.



Source: Wiki/kntry

Overgrown grass shows how nature is slowly reclaiming the seabound site

© Getty



A 1937 Chevrolet coupe rusts away in this Old West relic

© Getty

DID YOU KNOW?
Chinese and Korean prisoners of war were forced to work on Hashima Island.

Bodie

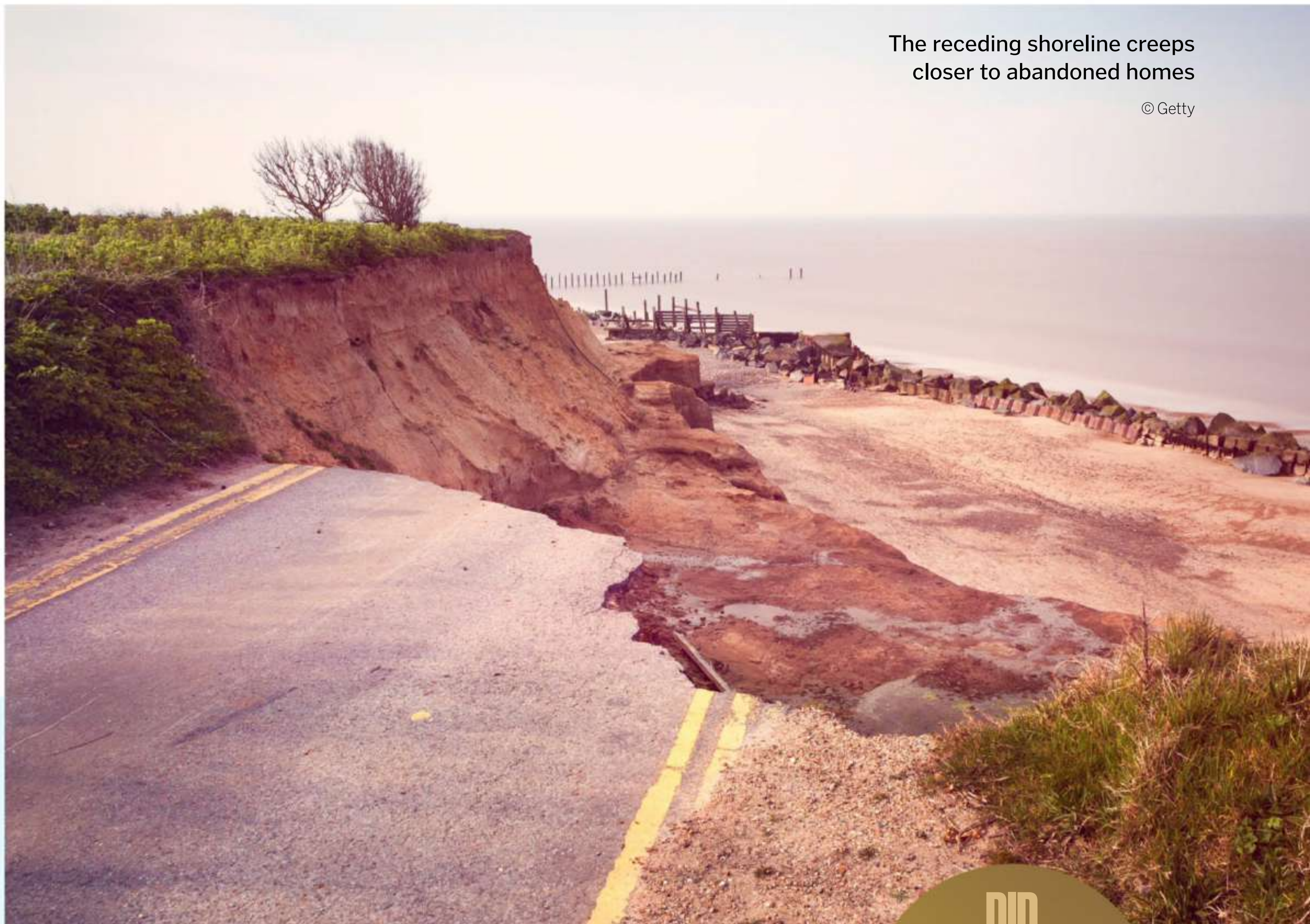
Location: United States **Abandoned:** 1915

Following the California Gold Rush, prospectors first found the precious metal at this site in 1859, though the town didn't boom until around 18 years later. Growing rapidly to have a population of around 10,000 as miners flocked to make their fortune, by 1880 signs of decline began to show as men went to chase riches elsewhere. Never quite the same as it was in its prime, Bodie was referred to as a ghost town by 1915, though a few residents remained until the 1940s. Today it serves as a window into the Wild West, with its saloons and Methodist Church being among the most interesting attractions for visitors.

Happisburgh

Location: UK
Abandoned: N/A

Though this village in Norfolk is inhabited and not technically a ghost town, erosion along the coast is forcing those living near the cliff's edge to evacuate before the land beneath them crumbles away, leaving their houses empty as they await their fate. Homes that sat six metres from the sea in 1998 now sit precariously on the edge, deserted by their previous owners. Though sea defences were built in 1959, and groynes added in 1968 to slow the process, the village will continue to shrink as it is battered by the sea.

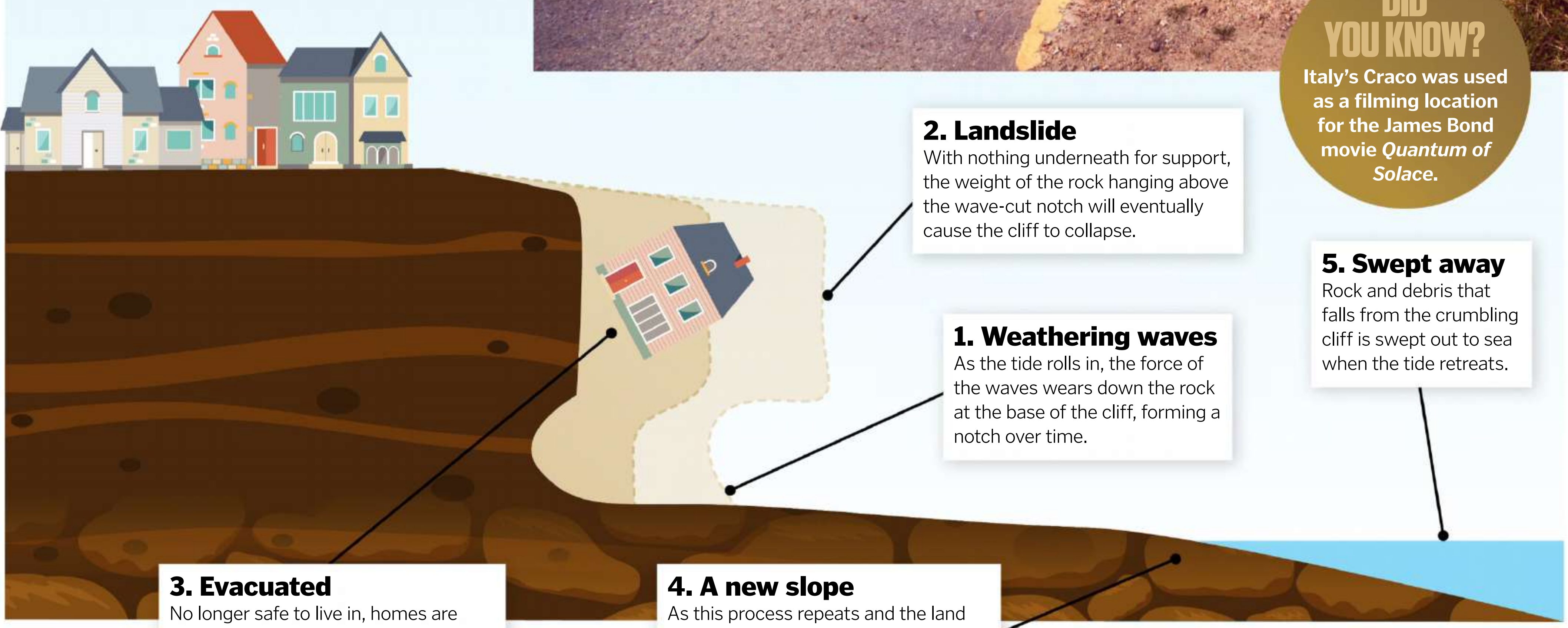


The receding shoreline creeps closer to abandoned homes

© Getty

Coastal erosion

How the power of the waves cuts into cliffs



1. Weathering waves
As the tide rolls in, the force of the waves wears down the rock at the base of the cliff, forming a notch over time.

2. Landslide
With nothing underneath for support, the weight of the rock hanging above the wave-cut notch will eventually cause the cliff to collapse.

3. Evacuated
No longer safe to live in, homes are abandoned. Buildings are usually demolished to avoid dangerous debris.

4. A new slope
As this process repeats and the land recedes, a low slope forms at the base of the cliff, called a wave-cut platform.

5. Swept away
Rock and debris that falls from the crumbling cliff is swept out to sea when the tide retreats.

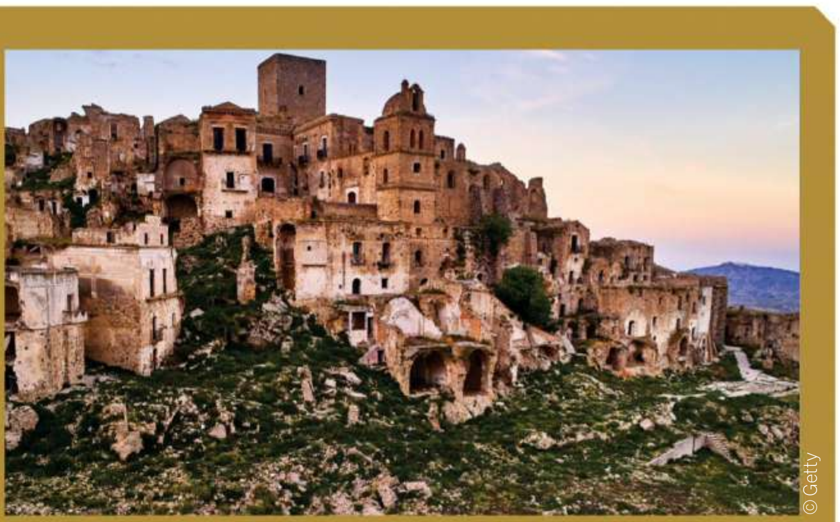
© Getty

DID YOU KNOW?
Italy's Craco was used as a filming location for the James Bond movie *Quantum of Solace.*

Craco

Location: Italy **Abandoned:** 1980

In this ancient Italian town, tombs have been found dating back as far as the 8th century BCE. Surviving on its strategic summit for thousands of years, the town grew exponentially between the 13th and 15th centuries, with a university and four large palazzi (palaces) being raised. It had an average population of around 1,500 in 1656, when a plague struck, decimating the inhabitants. By 1815 the town was thriving again, though poor agriculture meant 1,300 residents emigrated to America by 1922. Landslides caused evacuation in 1963, with flooding in 1972 worsening the town's condition. The 1980 Irpinia earthquake dealt a final blow.



© Getty

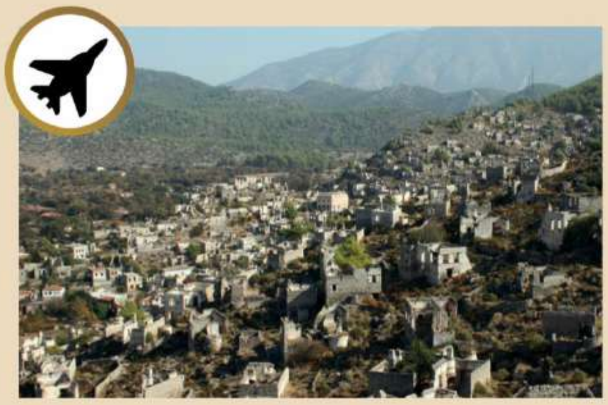
This empty town has become a popular filming location

DID YOU KNOW? *Hashima Island is also called Gunkanjima, meaning Battleship Island, due to its shape*

Kayaköy

Location: Turkey
Abandoned: 1923

The massacre of this town's Greek inhabitants during World War I decimated much of its population. After the Greco-Turkish War broke out in 1919, a population exchange between Greece and Turkey meant that any survivors were forbidden from returning to their former homes and were forced to return to Greece.



© Getty

Glenrio

Location: United States
Abandoned: 1975

This former railroad town sits right on the border between New Mexico and Texas along historic Route 66. Construction of Interstate 40 doomed the local economy when it bypassed the town completely. With less people passing through, it was no longer viable. Remains include an old motel, cafe, service station and post office.

© Getty

Kolmanskop

Location: Namibia
Abandoned: 1956

It was built atop a diamond-rich area, with German-style architecture, but in 1928 many left to head 170 miles south for richer deposits. At the outbreak of World War II, the town was in decline due to the diamonds drying up. After its abandonment, geological shifts flooded buildings with desert sand, making reclamation unlikely.

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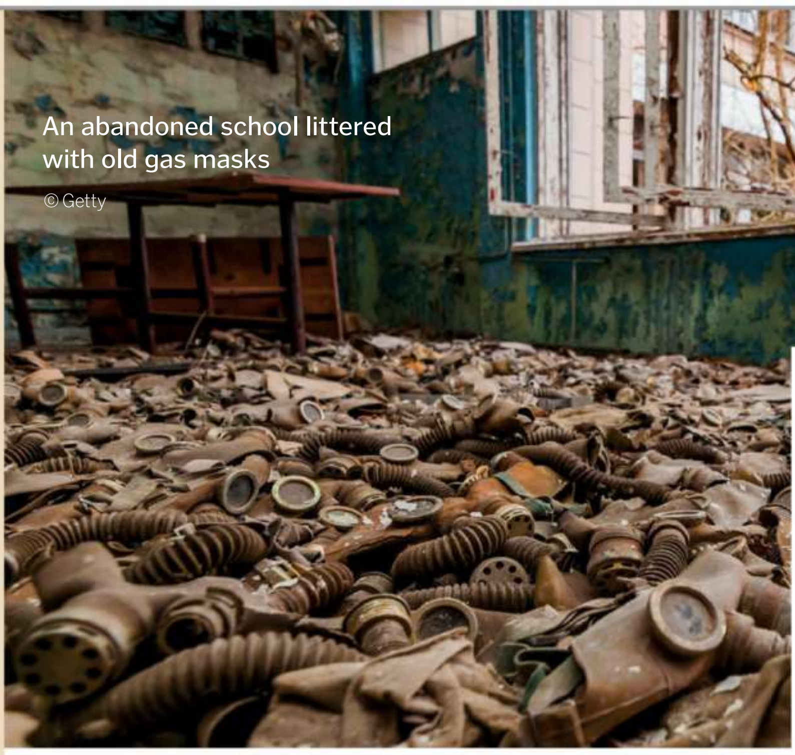


An abandoned school littered with old gas masks

© Getty

© Getty

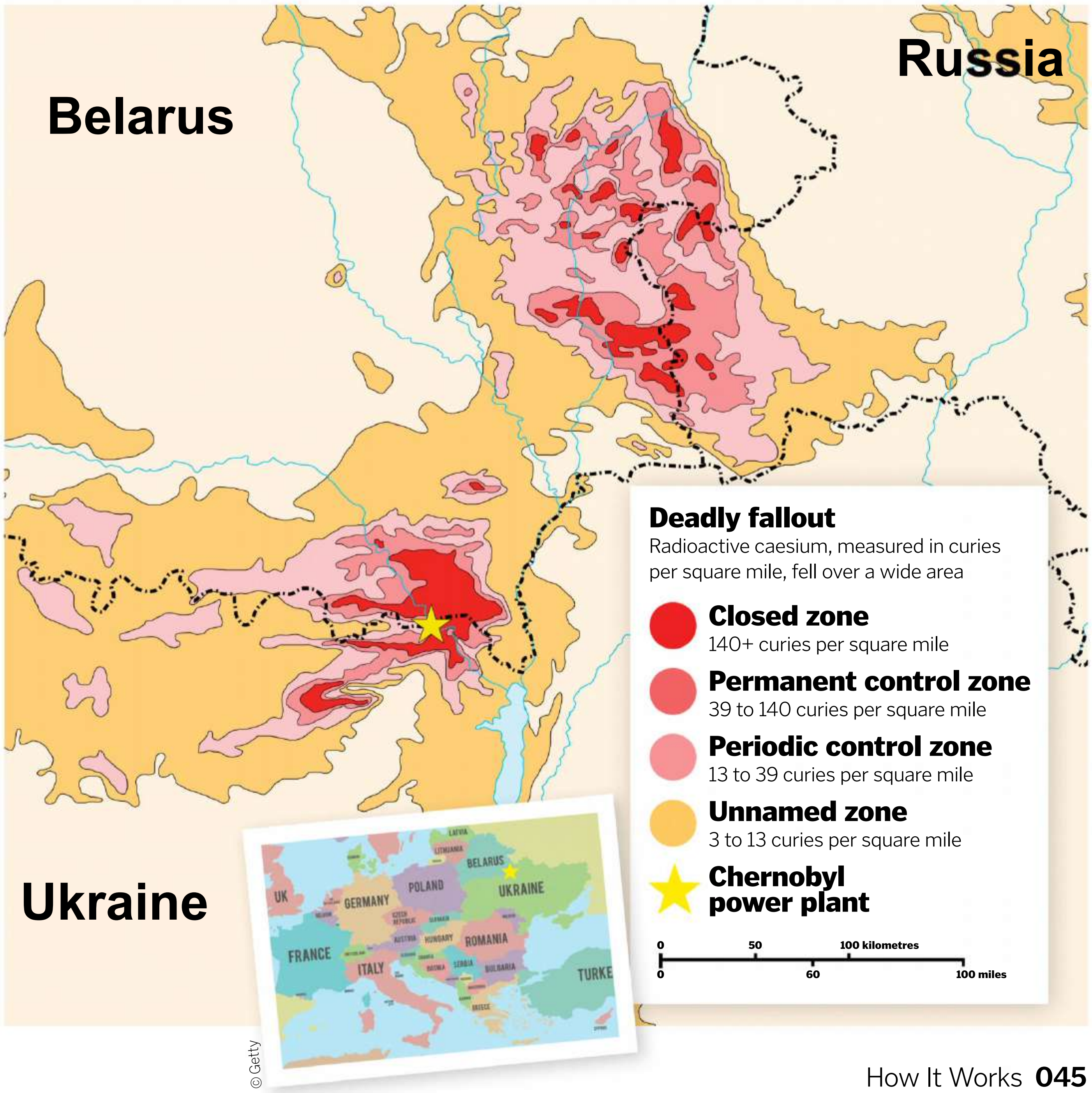
Pripyat is still unsafe to live in because of lingering radiation

Pripyat

Location: Ukraine **Abandoned:** 1986

The meltdown at the Chernobyl Nuclear Power Plant on 26 April 1986 rendered the nearby city of Pripyat, which was built to house the plant's scientists and workers, unlivable because of the radioactive fallout from the disaster. Its 49,360 residents had to be evacuated quickly due to the danger posed by the plant, leaving their belongings behind as they ran for their lives. Though only 54 residents passed away after short-term exposure to radiation, many others suffered from acute radiation sickness.

An 18-mile exclusion zone around the plant was cordoned off by Ukrainian authorities, but radiation levels have dropped enough in recent years to allow former residents, urban explorers and dark tourists to visit for short periods of time. It will still be thousands of years before radiation levels have dropped to a safe level for human habitation.



Russia
Belarus
Ukraine
Deadly fallout
Radioactive caesium, measured in curies per square mile, fell over a wide area
🟥 Closed zone
140+ curies per square mile
🟥 Permanent control zone
39 to 140 curies per square mile
🟥 Periodic control zone
13 to 39 curies per square mile
🟧 Unnamed zone
3 to 13 curies per square mile
★ Chernobyl power plant
0
50
100 kilometres
0
60
100 miles
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POLAND
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ROMANIA
TURKE

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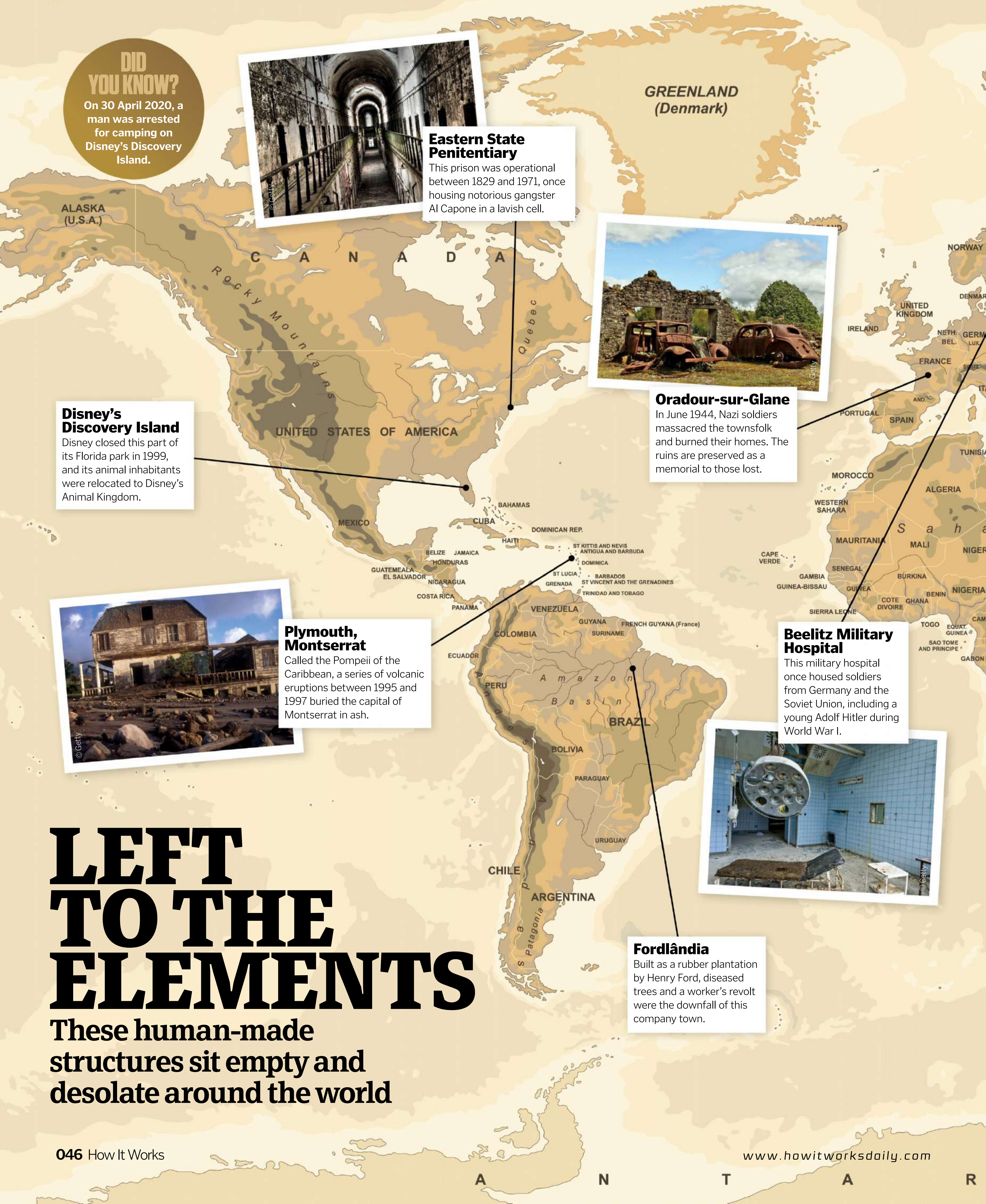
Source: Wiki/CIA Factbook, Sting (vectorisation), MTruch (English translation)

LEFT TO THE ELEMENTS

These human-made structures sit empty and desolate around the world

DID YOU KNOW?

On 30 April 2020, a man was arrested for camping on Disney's Discovery Island.



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JAMAICA
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GUATEMEALA
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
ST KITTS AND NEVIS
ANTIGUA AND BARBUDA
DOMINICA
ST LUCIA
BARBADOS
GRENADA
ST VINCENT AND THE GRENADINES
TRINIDAD AND TOBAGO
VENEZUELA
GUYANA
SURINAME
FRENCH GUYANA (France)
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NIGERIA
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GHANA
SIERRA LEONE
TOGO
EQUAT. GUINEA
SAO TOME AND PRINCIPE
GABON
A N T A R

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Eastern State Penitentiary

This prison was operational between 1829 and 1971, once housing notorious gangster Al Capone in a lavish cell.

Oradour-sur-Glane

In June 1944, Nazi soldiers massacred the townsfolk and burned their homes. The ruins are preserved as a memorial to those lost.

Disney's Discovery Island

Disney closed this part of its Florida park in 1999, and its animal inhabitants were relocated to Disney's Animal Kingdom.

Plymouth, Montserrat

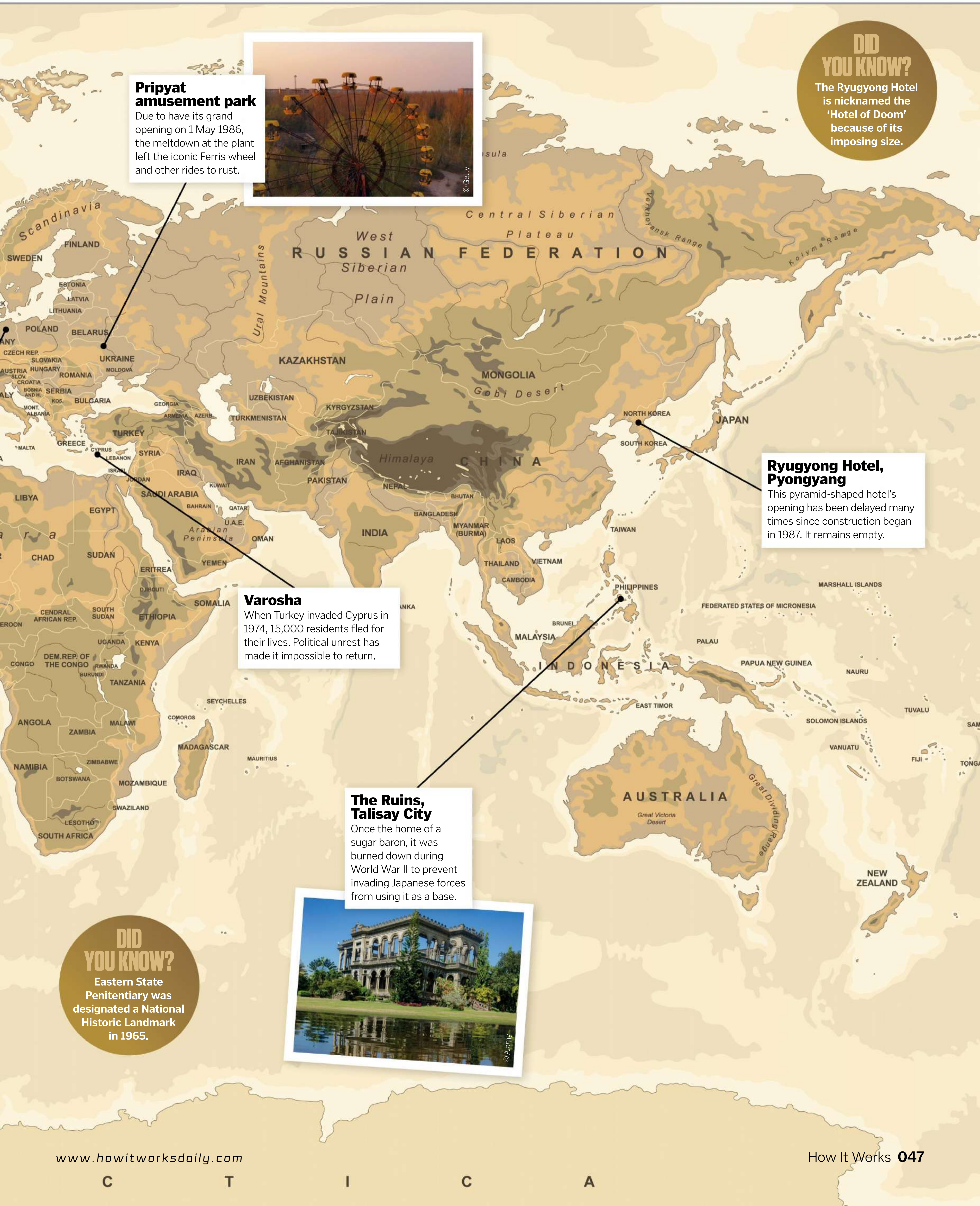
Called the Pompeii of the Caribbean, a series of volcanic eruptions between 1995 and 1997 buried the capital of Montserrat in ash.

Beelitz Military Hospital

This military hospital once housed soldiers from Germany and the Soviet Union, including a young Adolf Hitler during World War I.

Fordlândia

Built as a rubber plantation by Henry Ford, diseased trees and a worker's revolt were the downfall of this company town.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CENDRAL AFRICAN REP.
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UGANDA
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PAKISTAN
NEPAL
BHUTAN
INDIA
BANGLADESH
Ural Mountains
West Siberian Plain
RUSSIAN FEDERATION
Central Siberian Plateau
Verkhoyansk Range
Kolyma Range
sula
MONGOLIA
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FIJI
TONGA
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Great Victoria Desert
Great Dividing Range
NEW ZEALAND
ANKA
C T I C A

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Pripyat amusement park
Due to have its grand opening on 1 May 1986, the meltdown at the plant left the iconic Ferris wheel and other rides to rust.

Ryugyong Hotel, Pyongyang
This pyramid-shaped hotel's opening has been delayed many times since construction began in 1987. It remains empty.

Varosha
When Turkey invaded Cyprus in 1974, 15,000 residents fled for their lives. Political unrest has made it impossible to return.

The Ruins, Talisay City
Once the home of a sugar baron, it was burned down during World War II to prevent invading Japanese forces from using it as a base.

DID YOU KNOW?
The Ryugyong Hotel is nicknamed the 'Hotel of Doom' because of its imposing size.

DID YOU KNOW?
Eastern State Penitentiary was designated a National Historic Landmark in 1965.

HEROES OF… TECHNOLOGY

Ovshinsky invented ovonics, which converts materials from a non-conducting state to a conducting state

© Getty

Stanford speaks to his wife Iris outside Energy Conversion Devices, the company they started together

gy Conversion

© Getty

A life's work

Whatever path his life took, this inventor had a vision

1922
Stanford Ovshinsky is born on 24 November in Akron, Ohio.

1941
After finishing high school, Ovshinsky begins working as a tool-maker and machinist.

1946
His first invention, an automatic high-speed lathe, improves the efficiency of wood and metal shaping.

1951
Ovshinsky becomes the director of research at the Hupp Motor Company and moves to Detroit.

1959
He patents a mechanical model of a nerve cell called the Ovitron.

DID YOU KNOW? *Aged 88, Ovshinsky was working on a machine that would make solar energy cheaper than fossil fuels*

Stanford Ovshinsky

The environmentalist and tech genius whose inventions transformed the devices in your home

You might not know much about Stanford Ovshinsky, but you are sure to have encountered his work. He is behind the batteries in our smartphones, the flat screen televisions on our walls and the rise of electric vehicles. Many of his inventions arose from his work in physics, where he discovered how to create an electrical current in materials that had not shown this capability before. In doing so, he was able to change the design of devices like the television. Before flat screens were made commercially available in the late 1990s, televisions were bulky and weighty, so hanging them on the wall simply wasn't an option. But Ovshinsky had a vision. By proving that thin screens could conduct electricity and produce the same quality of image, the world of home entertainment was transformed.

One of his discoveries, which became most widespread in application was something called phase-change memory. During his studies of chalcogens, the elements below oxygen in the periodic table, Ovshinsky found that he could change the arrangement of their atoms by heating them. This led to the invention of the technology found in rewritable CDs. When these discs are burned in production, lasers are used to create grooves, changing the structure of their surfaces to store data. But with Ovshinsky's new technology, rewritable CDs could be heated and returned to a groove-free surface. This wiped them, ready to be reused.

From 1960, he dedicated his life and scientific discoveries to producing more sustainable energy resources. The science he had previously uncovered enabled him to make some big changes in the area he was passionate about: the environment. He had observed the world's dependence on oil and the devastation that it could cause through pollution and war. Using his own science discoveries, Ovshinsky's two most successful inventions for this cause were thin solar panels and nickel-metal hydride batteries. Both were made possible due to the nature of his experiments, which gave unstructured materials the properties that he required. He made solar panels more readily available by using much cheaper non-crystallised silicon, as well as inventing non-toxic rechargeable batteries that were ideal for storing the energy required to power hybrid electric cars.

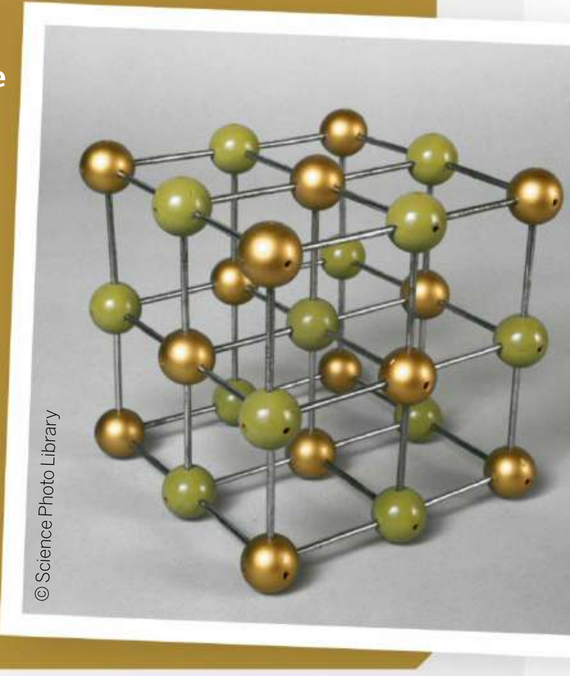
© Getty

Ovshinsky moved to Michigan in 1951, where he lived for the rest of his life

THE BIG IDEA

60 years of 'the Ovshinsky effect'

Before 1961, scientists believed that only crystalline structures could be semiconductors. These materials were composed of a series of lattices, which allowed any current passed through to do so in a controlled way. However, this accepted science didn't stop Ovshinsky from exploring new possibilities. He began to experiment with materials such as glass to see whether they could also serve as conductors. Before he explored his theory, it was assumed that the structure of glass was too irregular, and that it would be impossible for electrons to move together effectively to produce a current. By adding a certain voltage to the glass, Ovshinsky found that he was able to temporarily turn its structure into crystalline lattices. Through his discovery, Ovshinsky made it possible to use a wider range of cheaper and more accessible materials when creating electrical appliances.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A crystalline structure is an ordered arrangement of atoms or molecules

FIVE THINGS TO KNOW ABOUT...

STANFORD OVSHINSKY

1 **Father's influence** He named his first invention the 'Benjamin Center Drive' after his father Benjamin Ovshinsky, a Jewish immigrant from Lithuania.

2 **Fastest machinery** Ovshinsky's high-speed lathe invention was used during the Korean War to make artillery shells, as it could produce them ten-times faster than other machines could.

3 **Inventor over businessman** The business Ovshinsky set up with his wife began to lose money annually for decades. However, he said: "A real inventor is not motivated by money. It's about the idea and the creation."

4 **Self-taught scientist** Having received no further education after high school, Ovshinsky's talents in science were learned at home while he worked as a tool-maker.

5 **Powering the Prius** Among his inventions was the Toyota Prius' nickel-metal hydride battery. It is the world's first successful hybrid car, as well as the best selling.

1960
Stanford and his wife Iris start a company called Energy Conversion Laboratories, which produces solar panels and rechargeable batteries.

1961
He applies for a patent for 'the Ovshinsky Effect'.

1966
With the aim of turning chunky televisions into today's flat screens, Ovshinsky invents the technology which allows thin glass screens to produce pixels.

1979
Following the rise of coal mining, the inventor seeks more sustainable options. He begins the mass production of solar panels.

1982
Ovshinsky tells workers in his lab that his nickel-metal hybrid battery will allow for energy-efficient cars. These would come into widespread use within 20 years.

2012
On 17 October, Ovshinsky passes away at the age of 89, with more than 400 patents to his name.

SMARTER KITCHENS

HOW THE LATEST TECHNOLOGY IS CHANGING THE WAY WE INTERACT WITH EVERYDAY APPLIANCES AND HOW WE PREPARE OUR FOOD

Words by **Ailsa Harvey**

DID YOU KNOW? *The average person in the UK spends 2.8 hours a day in their kitchen*

© Getty

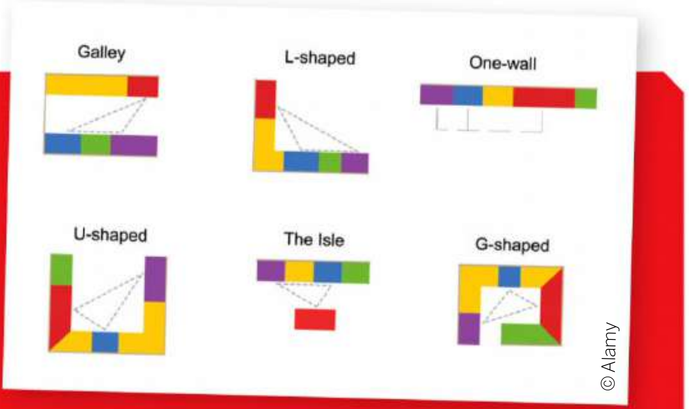
How much time do you spend in the kitchen? Whether you're whiling away hours a week, stirring on the sweltering stovetop, or you frequently use the dining table as a place for work and rest, the kitchen can become a hub of social activity. Because we have spent longer amounts of time in our kitchens over the years, they have become larger and more open spaces. But when it comes to cooking, the average adult today spends almost half the time preparing meals as their parents would have at the same age. Although some of this could be down to lazy chefs, one factor that is making the kitchen experience simpler, quicker and more luxurious is improvements in culinary technology.

As internet connectivity increases the number of 'smart' products in our homes, kitchens are no exception. Smart kitchens are equipped with electronic devices that are designed to save time and energy while maximising the comfort and experience of their user. They often allow you to control them through a smartphone using connected applications. Now you don't even need to be within the walls of your home to turn on a cooking appliance.

It might be their main purpose, but modern kitchens aren't all about preparing food. Often used as a place to wash clothes, wash and store dishes, gather as a household and eat, this room is likely to hold more electronic devices than any other. Kitchens have always been associated with various chores and tasks. This is evident from the medieval days, when servants would occupy kitchens, cutting wood for the fires and washing household dishes, to the practical yet hidden kitchens of the early to mid-1900s. Modern kitchens are no longer hidden, but as technology advances, we don't have to work as hard in them as our ancestors did. Through the emergence of smart kitchens, technology is replacing much of the hard labour and emulating some of the fine details of our culinary skills.

Planning your layout: the zoning method

The first task when planning a modern kitchen is to consider the layout. The five main zones that make up today's kitchens are for consumables, non-consumables, cleaning, preparation and cooking. The consumables zone is where most of your food is kept, including the fridge for cold products and cupboard storage, while the non-consumables zone holds utensils and other kitchen equipment. The cleaning zone includes the sink and possibly a dishwasher. The positions of these appliances are often unchangeable due to plumbing. The preparation zone is the area in the kitchen where you chop vegetables, mix ingredients and do other food prep. Finally, the cooking zone contains the stove, oven and microwave. It is important to consider practicality as well as aesthetics to make movement between these zones smooth.



© Alamy

The 'kitchen work triangle' connects the sink, fridge and stove. The kitchen is believed to be most practical when the three are arranged in a triangle

The evolution of the kitchen

Discover how this room has changed over the centuries

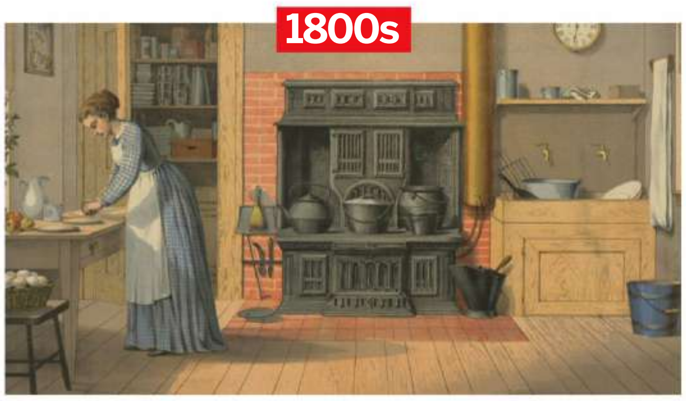
MEDIEVAL KITCHENS

Any guests entering a wealthy household during these times would stay far from the kitchen, as they were dark and often smelly rooms. But there was no separate kitchen in poor houses. Open flames were the only option when it came to cooking food, making homes hot and smoky.

1700s

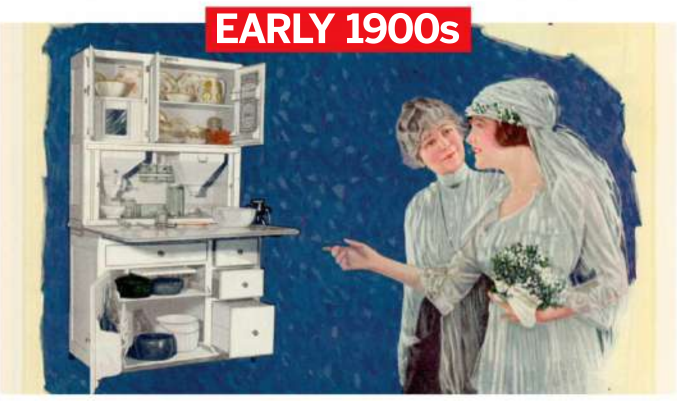
A wider range of dishes and utensils emerged at this time. Many cooking methods were similar to today, but items such as the fork were uncommon. While upper-class kitchenware was made of silver, cups and plates were generally made of tin, ceramics and wood.

1800s



Most kitchens were found on the bottom floor of homes. Kept out of the way from the main entrance, this room was generally only used for cooking, while most had a separate room for washing dishes. Cooking became more efficient in the 1850s with cast-iron stoves, which required less fuel.

EARLY 1900s



Hoosier cabinets became a must-have in most kitchens. These combined storage space with food preparation areas to make cooking a more efficient process. They contained pull-out work surfaces, cupboards for ingredients and drawers for utensils.

LATE 1900s

In the 1970s, wood kitchens surged in popularity, creating uniform kitchens that had a warm and welcoming appeal. The 1980s saw the addition of white, shiny surfaces to these wooden designs, while the 1990s saw a rise in modern, almost completely white furnishings and goods.

TODAY

Modern kitchens focus on light, open spaces. Smooth, curved surfaces and the removal of handles from cabinets are common. Beyond aesthetics, the incorporation of wireless devices to produce smart kitchen appliances means that kitchens are becoming more automated.

6x © Alamy

INSIDE A SMART KITCHEN

THESE MODERN APPLIANCES COMBINE EFFICIENCY, ENTERTAINMENT AND STYLE IN ONE ROOM

AR ZONE! SCAN HERE

Illustration by © Nicholas Forder

Social cooking

Called the GE Kitchen Hub, this smart hood is perfectly positioned to incorporate video calls and display recipes while working as an extractor fan. If you're making a meal that requires a lot of monitoring, you can find yourself bored while you stand over the kitchen hob. Featuring a video call application, the Kitchen Hub means you can easily chat with your friends hands-free while you spend time cooking your meals. Another useful feature is a recipe application, which displays each step of the recipe one at a time. You can move on to the next step by using voice commands, and when it reaches a step that says 'preheat the oven' or 'turn on the hob to medium heat', connected appliances will turn on by themselves.

© GE Appliances

With front-facing and downwards-facing cameras, you can film yourself and an aerial view of your cooking

Sound bar speakers

The trend in open-plan homes and the increasing popularity of cooking has resulted in kitchens evolving as social spaces. Whether becoming a gathering place for a party at home or just one of the preferred rooms to spend daily life, many people look to incorporate music into their modern kitchens. The Sound Bar by Magnet Kitchens is designed especially for kitchens, blending in with the surrounding cabinets. The long, vertical bars are built to fill a large, open space with sound and can be controlled via Bluetooth from multiple devices.

© Magnet Kitchens

A light shines near the power button to show that the speaker is on

Precision pouring

The Blanco EVOL-S is designed to reduce wasted water while making measurements easier. If you're someone who is often referring to a recipe book, you will know how important it is to keep measurements consistent for the right results. However, sometimes this can be hard to judge. This tap has a dial on the side that you can set to the exact volume required. You tap the side to pour the allocated volume before it automatically stops. This means that when filling up larger containers, you can step away from the sink without having to constantly monitor the water level.

© Blanco

Blanco's EVOL-S tap has a pull-out hose to fill more difficult containers

DID YOU KNOW? *The global smart kitchen market is predicted to reach over $43 billion [£31 billion] by 2027*

© Samsung

With four temperature settings, compartments can be quickly changed from fridge to freezer

Family Hub fridge

Samsung's Family Hub smart fridge allows you to manage the contents of your fridge whether you're in the kitchen or out at the shop. The touchscreen panel on the fridge door can display the contents thanks to the cameras inside, meaning that you don't have to open the door and lose cold air. When you place food onto a shelf, you can add the expiry dates using the screen. Connected to a smartphone application, you're notified when food is about to expire, reducing waste.

As well as keeping your food chilled and organised, this fridge aims to keep the whole family organised too. The digital camera makes it easy to keep track of plans for different members of the household, with the next event flashing up on the screen as a reminder. And just because it's all electronic doesn't mean it has to lose its personal touch. Children can still add pictures to the fridge door by drawing with their finger, and messages to other family members can be written.

© Magnet Kitchens

Cabinets can be kept open, appearing as wall shelves, or tucked away behind cupboards

Compact cabinets

At the touch of a button, these shelves extend down from behind the cabinets, displaying your kitchen utensils and other products that were previously out of sight. With the goal of creating an uncluttered space, Magnet Kitchens' Cabinet Plus keeps items accessible and visible, but only when needed.

© LG Appliances

LG's smart oven can be connected to Amazon Alexa or Google Assistant for voice-controlled operation

InstaView oven

Accurately determining the readiness of your oven bake without being tempted to open the oven door isn't an easy task. This has always been the best way to see the details of the food, such as its colour and texture, but it also leads to the carefully controlled heat being released. LG's InstaView oven has a bright light inside which can be turned on by knocking twice on the door. This provides you with a clear view of your meal's progress.

Some of its cooking features include Air Fry and Air Sous Vide. Oven air frying produces fried foods without needing to preheat and also uses less oil than conventional stovetop frying. Meanwhile, the Sous Vide mode controls the airflow at precise, low temperatures around vacuum-sealed bags in order to maintain all the essential flavours inside.

5 INTELLIGENT DEVICES

© Revolution cooking

1 Perfect your toast
This touchscreen toaster is designed for 63 bread types, including bagels, muffins and waffles. Before toasting you can select your toasting level, with the screen displaying what your bread will look like.

© Fellow Products

2 Brew in advance
The Stagg EKG Electric Kettle can be turned on remotely when connected to the mobile phone app. Once boiled the kettle can keep the water at your desired temperature for 60 minutes.

© GeniCan

3 Track the trash
This small device attaches to the edge of your bin to keep your shopping list up to date. When you throw away an empty packet, scanning the barcode will add the item to your digital shopping list.

© GE Appliances

4 Monitor microwaving
Using voice commands, you can set the microwave's power and time. Alternatively, scanning the barcode on the food packet enables the microwave to cook for the required time.

© HAPILABS

5 Listen to your utensils
It can be difficult to register when we are eating too fast. HAPIfork is a fork with a motion sensor inside, which can track when it is being lifted. If you eat too quickly, it vibrates to alert you.

Folding phone teardown

Take a look inside the Samsung Galaxy Z Fold 2 smartphone

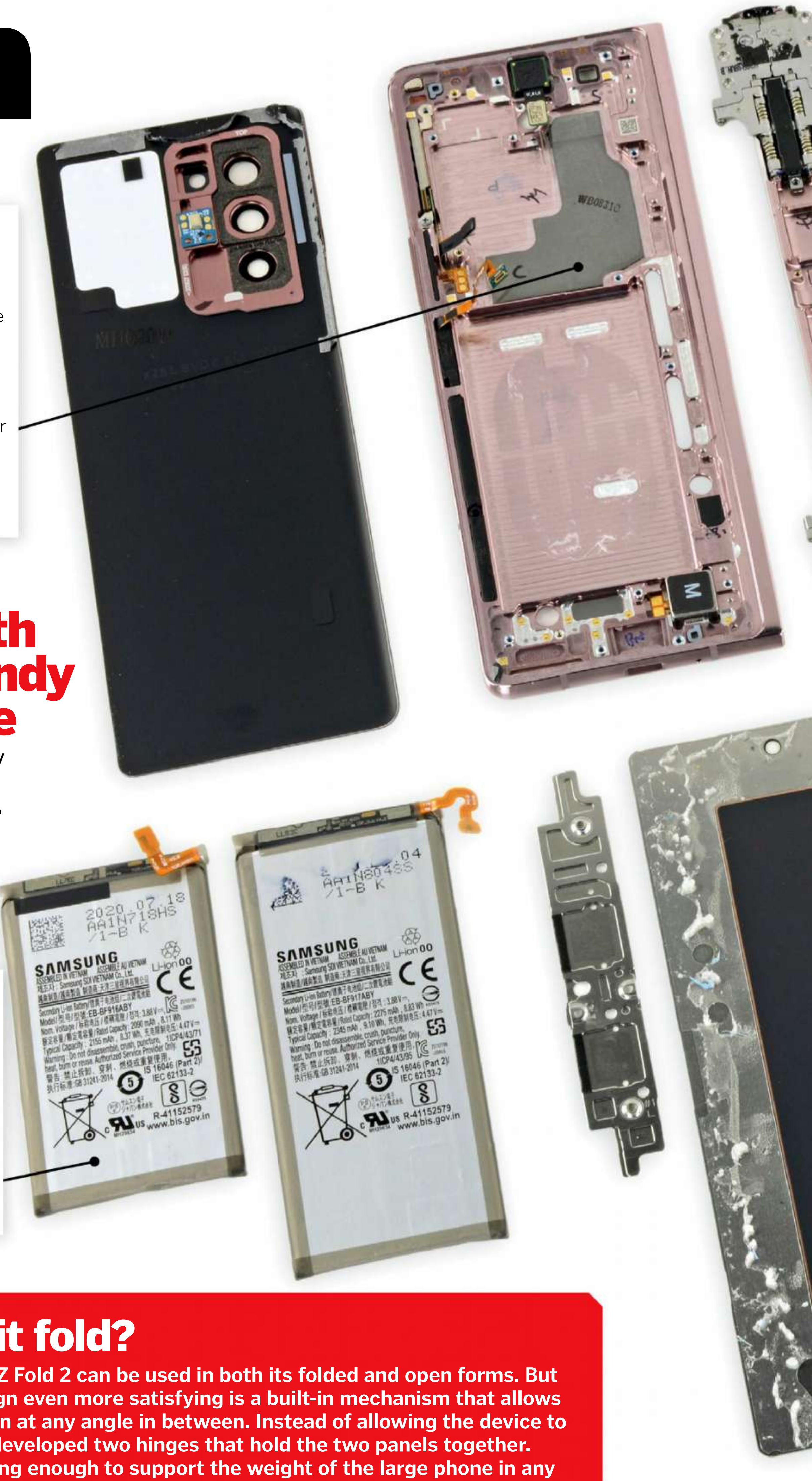
Tablets are the ideal portable device for viewing videos and images, playing games and navigating the web on a larger screen. But when compared to phones, they just aren't as practical for using on the move. Since 2018, however, a handful of mobile phone companies have shown that choosing between a tablet and smartphone isn't always necessary. Now you can have them both in one device.

One of these companies is Samsung, who released the Galaxy Z Fold 2 in September 2020. This device can be opened like a book to be used as either a thin, standard-sized smartphone, a tablet-sized screen or as a split screen for using two separate applications simultaneously. The device has one screen on the front for phone use and a larger, foldable screen inside. The display automatically switches between the two when clicked open.

How is it possible for a solid screen to have this flexibility? This is all down to the type of screen used. The active-matrix organic light-emitting diode (AMOLED) screen in Samsung's new model enables it to be thinner due to the way it projects light. Instead of using screen technology common in most mobile devices, requiring an extra layer that provides a backlight, the pixels in AMOLED screens produce their own light. This thinner option gives the phone further benefits to curvature, such as a more energy efficient screen. As the pixels can be individually controlled, some can be turned off when displaying dark blacks. This saves more energy than standard screens, which work to block the continuous backlight to create darkness when displaying black, consuming much more power over time.

Beneath the bendy surface

What technology lies under this adaptive screen?



Graphite thermal pad
Instead of using copper to draw heat away from the device and prevent overheating, this model uses a graphite pad. Graphite has similar heat-conduction abilities to copper, while being a less weighty choice.

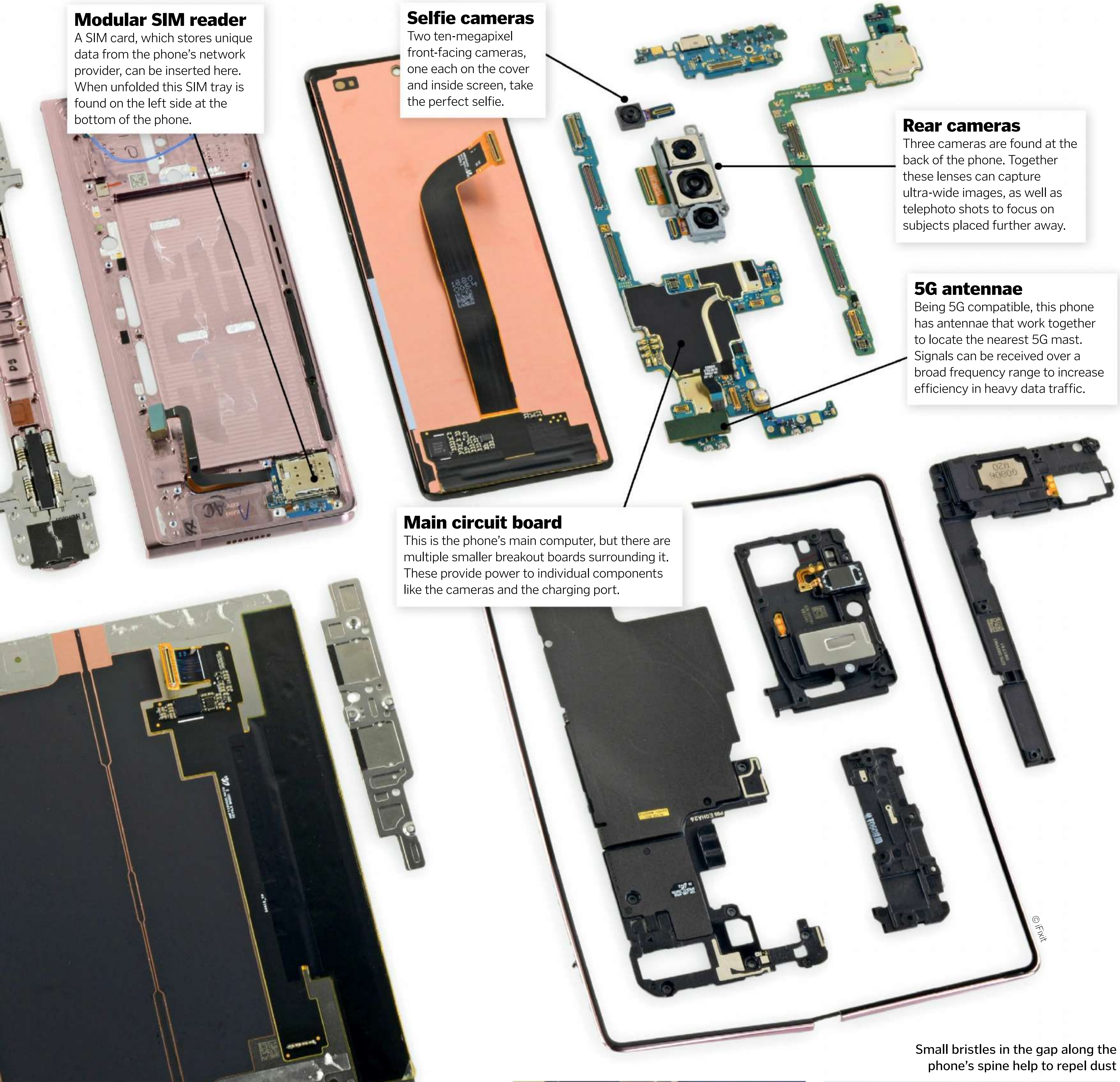
Batteries
The phone has two batteries – one for each half of the device. With power capacities of 9.1 and 8.37 watt-hours, this model has a longer battery life than the previous Galaxy Fold.

Strips of aluminium line the curved part of the screen, while larger pieces of metal border the flat areas of the screen for support

© iFixit

How does it fold?

The Samsung Galaxy Z Fold 2 can be used in both its folded and open forms. But what makes this design even more satisfying is a built-in mechanism that allows the phone to stay open at any angle in between. Instead of allowing the device to snap shut, Samsung developed two hinges that hold the two panels together. These hinges are strong enough to support the weight of the large phone in any position. But how do you engineer a delicate screen to fold and become flexible without it simply shattering? With this model, thin aluminium sticks are aligned along the part of the screen that bends. This strong material adds support to the display, while the gaps allow for movement. Using one solid piece of metal wouldn't work, as it would become too stiff to bend.



Modular SIM reader
A SIM card, which stores unique data from the phone's network provider, can be inserted here. When unfolded this SIM tray is found on the left side at the bottom of the phone.

Selfie cameras
Two ten-megapixel front-facing cameras, one each on the cover and inside screen, take the perfect selfie.

Rear cameras
Three cameras are found at the back of the phone. Together these lenses can capture ultra-wide images, as well as telephoto shots to focus on subjects placed further away.

5G antennae
Being 5G compatible, this phone has antennae that work together to locate the nearest 5G mast. Signals can be received over a broad frequency range to increase efficiency in heavy data traffic.

Main circuit board
This is the phone's main computer, but there are multiple smaller breakout boards surrounding it. These provide power to individual components like the cameras and the charging port.

Folding screen
The 7.6-inch-wide AMOLED display can be folded in half to change between a tablet-sized phone and a chunkier-but-narrow device that fits in one hand.

© iFixit

5G
Galaxy Z Fold2 5G

The Galaxy Z Fold 2 is Samsung's first 5G-compatible foldable phone

© Getty

Small bristles in the gap along the phone's spine help to repel dust

© Alamy

KENT RELIANT

©Alamy

SAVIOURS OF THE SEA

How salvage vessels recover floundering ships and deep-sea wrecks

Words by **Ailsa Harvey**

You don't have to venture too far out into the ocean to feel completely isolated and alone. As the sea covers over 70 per cent of Earth's surface, those who spend much of their lives boat-bound can travel over vast stretches of water each day. At any given time there are more than 50,000 cargo ships transporting goods overseas. This number doesn't even account for the multitude of cruise ships, fishing boats, personal yachts and other vessels.

No matter how experienced you are at sailing the seas, or how colossal your ship, this environment can be frighteningly unpredictable. Sometimes nature's plans are beyond the skilled hands of any expert seafarer. So what happens when an engine fails, the treacherous weather capsizes the boat or the captain's misjudgement of the water's depth results in a vessel running aground?

Luckily for the seafarers of today, communication technology means that seeking help can be as simple as tuning in to the local coastguard on the ship's radio. There are organisations equipped for and dedicated to promptly assisting with such sea emergencies, deploying a rescue boat. This carries the tools to retrieve both people and their ships, whether their vessel is lost deep underwater or is being engulfed by a blazing fire. But while these organisations have become vital rescue tools and carry out procedures similar to a salvage operation, their work isn't classed as salvage. For an operation to be classed as such, the rescuer will need to claim a salvage reward, which designated lifeboats won't usually do.

The idea behind this paid rescue came about when courts decided that those at sea needed more incentive to volunteer to save lives. Before technology enabled disaster-stricken boats to seek help from the shore, a stranded ship's crew could only scan the horizon, hoping for luck to be on their side. If by chance another boat was passing by, it was often in its occupants' best interests to help out. Other than the satisfaction of saving lives, any voluntary rescuers are entitled to a reward for their intervention.

The cost to a troubled boat can be great, and so it's common for a deal to be made between ships before any salvaging work takes place. Boat crews are then able to either accept or refuse to help. Today ships that fail to be salvaged can sink into the ocean, releasing large volumes of pollutants such as oil, fuel, plastic and other chemicals. For an intervention to be classed as true 'salvage', either the ship or its cargo needs to be saved from a situation which, without the assistance, would have led to its ruin.

CARGO SHIP CRASH

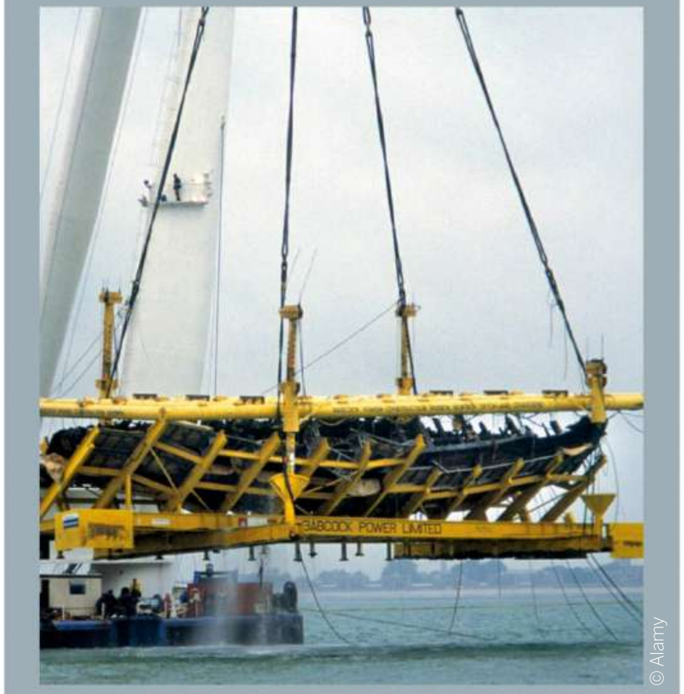
The MV Modern Express was a 164-metre-long cargo ship carrying trucks, wood and other construction materials from Gabon, Africa, to Le Havre, France. In January 2016, when it reached the Bay of Biscay – not far from the Spanish coast – it lost control in stormy seas and tipped onto its side. After the 22 crew members were rescued by helicopter, salvage vessels arrived and attempted to tow the large ship. The salvage crews waited for the weather to improve, and on 3 February the ship was successfully towed to a port in Bilbao, Spain. Once here it took three weeks to tilt the ship upright, achieved by filling the ballast tank in the boat. These compartments help to stabilise a ship.

It took three weeks of salvage attempts before the MV Modern Express was delivered to her owners for scrapping

Source: Wiki/Faith Takmakli

TUDOR TREASURE

The Mary Rose was a Tudor warship of King Henry VIII's navy. During the Battle of the Solent in 1545, the ship rolled onto its side, slowly sinking into the Solent strait. In 1836 the final resting place of the Mary Rose was discovered. Some of the ship's items were salvaged, such as the guns, and the fishermen who first discovered the location were paid a third of their value. It wasn't until 1982 that the ship was lifted off the seafloor. It was surrounded by a purpose-built lifting frame and ascended using a large crane.



© Alamy

The Mary Rose was lifted from the Solent between the Isle of Wight and Portsmouth

THE CAPSIZED CRUISE

When the cruise ship Costa Concordia was steered too close to the shore of the Italian island Isola del Giglio in January 2012, it hit underwater rocks, capsized and began to sink. The main rescue effort was to save the passengers, and during a six-hour procedure the majority of people were taken ashore. The wreck was then salvaged in September 2013. It was rolled upright onto an underwater platform before being lifted vertically. Costa Concordia was towed 200 miles to ship-breakers in Genoa, its home port, where its metals and materials were sold.

32 people died as a result of Costa Concordia's accident

© Getty

POST-WAR SABOTAGE

At Scapa Flow – a body of water surrounded by the Orkney Islands, Scotland – 52 ships of the German High Seas Fleet sank in June 1919. These ships weren't salvaged at the time because this mass sinking occurred on purpose, decided by the ships' Admiral.

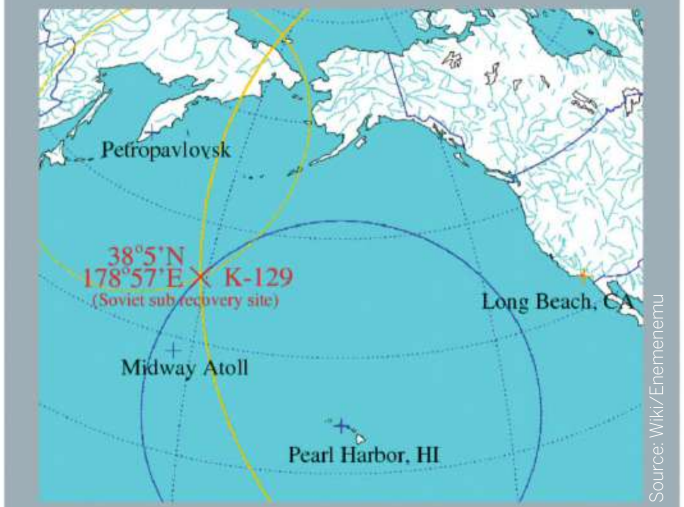
At the time, shortly after World War I, Germany was asked to surrender its warships. Not wanting to hand its fleet over to Britain, the German Navy flooded the ships with water and scuppered them. From 1922 to 1979, they were raised from the seafloor one by one, and their materials reused. Today only seven of these ships remain below the water.

© Getty

This anchor from a German battleship is pictured at Scapa Flow

SUBMARINE STEAL

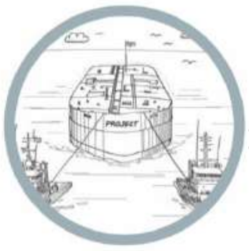
The K-129 was a nuclear-armed Soviet submarine carrying three ballistic nuclear missiles. After its unexplained disappearance in March 1968 and an unsuccessful Soviet search, the US set out to find and take the submarine for itself. This mission was given the codename Project Azorian. Within a few weeks the submarine was located, but the salvage operation wasn't going to be a simple one. The mission was to lift 1.4 million kilograms of submarine over a distance of 3.1 miles up through the water. A ship was designed especially to deploy a steel pipe with a large claw on the end. But the salvage attempt didn't go to plan as one of the fingers broke, sending some of the submarine falling back to the seabed. However, a section of the submarine was retrieved.



Source: Wiki/Enemenemu

The recovery site of submarine K-129 (in red)

5 SHIP-SAVING METHODS



© Getty

1 TOWING

If a vessel is suffering mechanical failure and can no longer produce its own power, it can be pulled to safety through the sea by another boat.

© Getty

2 PILOTAGE

Locals will know the seas better. Boat operators can be guided out of danger by someone knowledgeable of an area's conditions.

© Getty

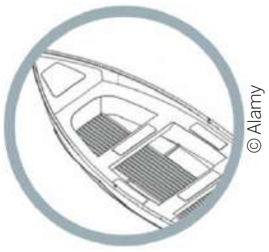
3 EXTINGUISHING

Salvage vessels are equipped with water cannons so that they can put out fires that have started on other boats from a safe distance.

© Getty

4 FLOATING

Attaching large airbags to the sides of a sinking vessel can keep it afloat while the remaining salvage takes place, allowing for prolonged rescue.



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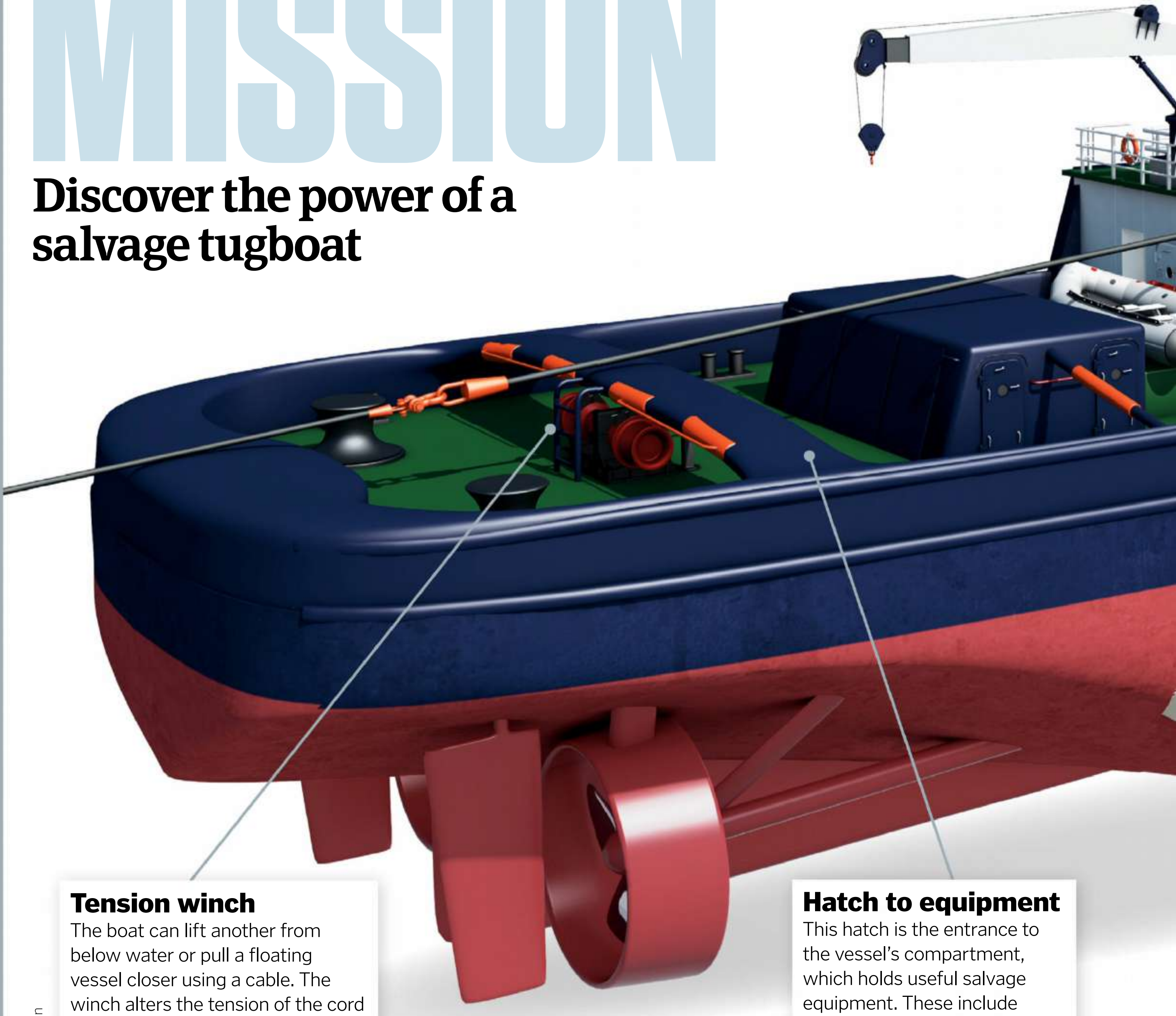
5 CLEARANCE

If a ship is beyond the point at which it can be prevented from sinking, salvage operations focus on removing people and valuable contents.

RECOVERY MISSION

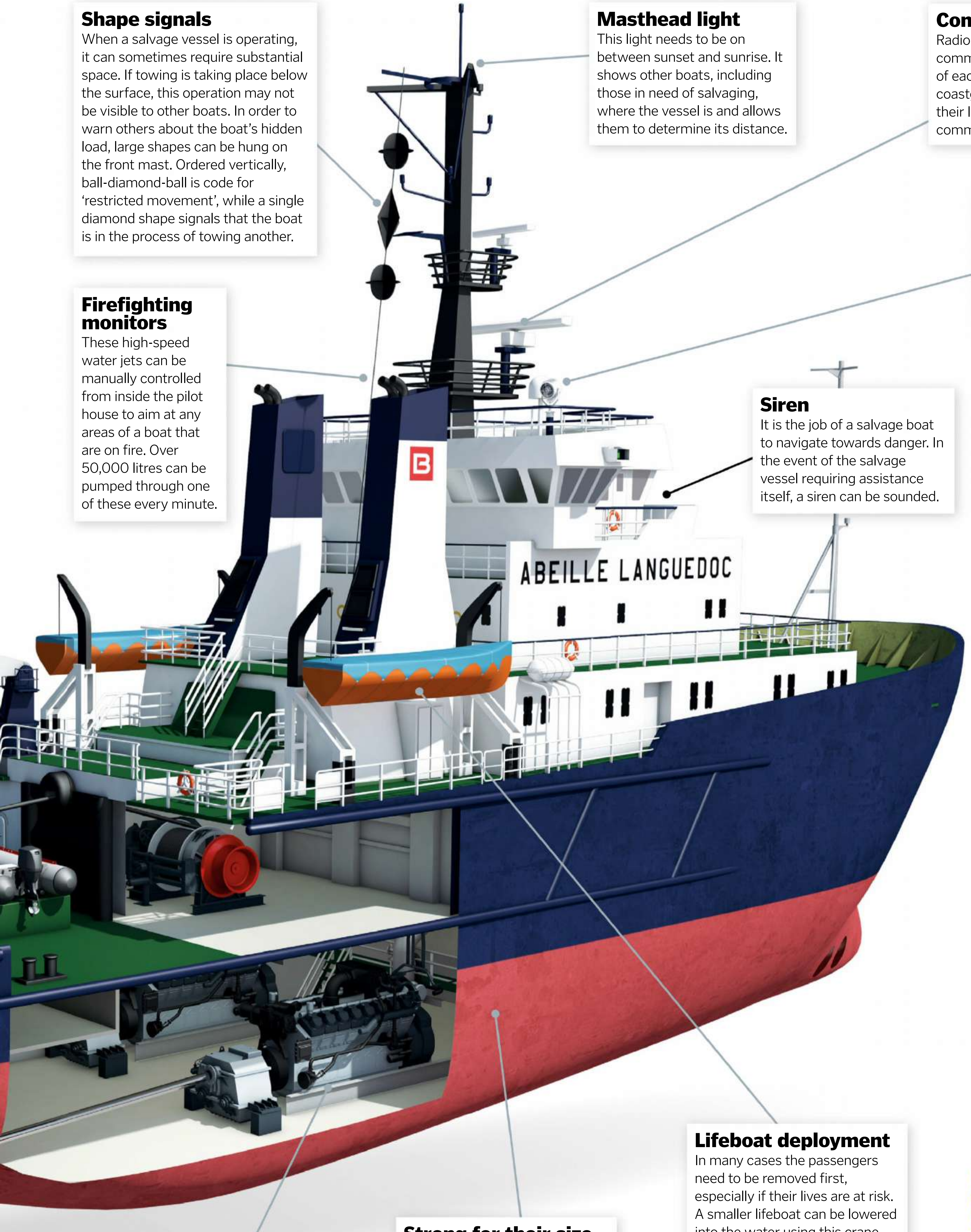
Discover the power of a salvage tugboat



© Adrian Mann

Tension winch
The boat can lift another from below water or pull a floating vessel closer using a cable. The winch alters the tension of the cord to pull the extra cable below deck, while the boat the cable attaches to is pulled closer to safety.

Hatch to equipment
This hatch is the entrance to the vessel's compartment, which holds useful salvage equipment. These include extra tow lines, firefighting gear, diving equipment and pumps for flooded boats.



Shape signals

When a salvage vessel is operating, it can sometimes require substantial space. If towing is taking place below the surface, this operation may not be visible to other boats. In order to warn others about the boat's hidden load, large shapes can be hung on the front mast. Ordered vertically, ball-diamond-ball is code for 'restricted movement', while a single diamond shape signals that the boat is in the process of towing another.

Masthead light

This light needs to be on between sunset and sunrise. It shows other boats, including those in need of salvaging, where the vessel is and allows them to determine its distance.

Communication

Radio antennae allow the boat to communicate any necessary details of each salvage mission to any coastguards they might be towing their load back to. They can also communicate with other vessels.

Morse lamp

This lamp can display long and short flashes to allow crew members to communicate with nearby boats using Morse code. This is particularly useful when a stranded ship has lost access to other communication systems.

Firefighting monitors

These high-speed water jets can be manually controlled from inside the pilot house to aim at any areas of a boat that are on fire. Over 50,000 litres can be pumped through one of these every minute.

Siren

It is the job of a salvage boat to navigate towards danger. In the event of the salvage vessel requiring assistance itself, a siren can be sounded.

Lifeboat deployment

In many cases the passengers need to be removed first, especially if their lives are at risk. A smaller lifeboat can be lowered into the water using this crane. This makes access to passengers easier and allows crew members to steer close to the other boat.

Strong for their size

Measuring just 20 to 30 metres in length, salvage tug boats have impressive strength for their size. Their large engines in relation to their size, combined with wide propellers, mean they move slowly but with a lot of thrust.

Double engines

A typical tugboat has two 500 to 2,500 kW diesel engines so it can salvage without assistance.

ABIDING BY MARITIME LAW

Many salvage operations are carried out by professional salvors, but other boats may be saved voluntarily by other ships which happen to be passing by. As long as those who assist the stricken vessel are not contractually obliged to do so, the efforts taken will be rewarded. This reward is based on the value of the vessel and the property that was recovered. As part of the 'no cure, no pay' principle, if some items are recovered but nothing is of particular value, then the salvor isn't entitled to payment. The boat and its occupants must also be in danger for the process to be classed as a true salvage operation.

US Coast Guards have become responsible for enforcing maritime law

Source: Wiki/The Institute of Heraldry

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Hydrogen: the future of cars?

We're heading towards a greener future, which could mean switching from petrol to hydrogen power

Our planet's changing ecosystem means that our cars need to change too, which is why electric cars have become popular and why hydrogen fuel cells are now being touted as another option for green motoring. There's plenty of good news. For starters, there's a lot of hydrogen about: it's Earth's most common element and it can be extracted from water, natural gas, biomass and several other sources. It's not toxic, in theory there's an almost unlimited supply and vehicles powered by hydrogen only emit water and heat, not harmful greenhouse gases.

Hydrogen cars have an impressive range when compared to electric vehicles, often matching conventional cars, and they can be refuelled in five minutes. That compares well to electric cars, which take hours to charge. They're quiet, too.

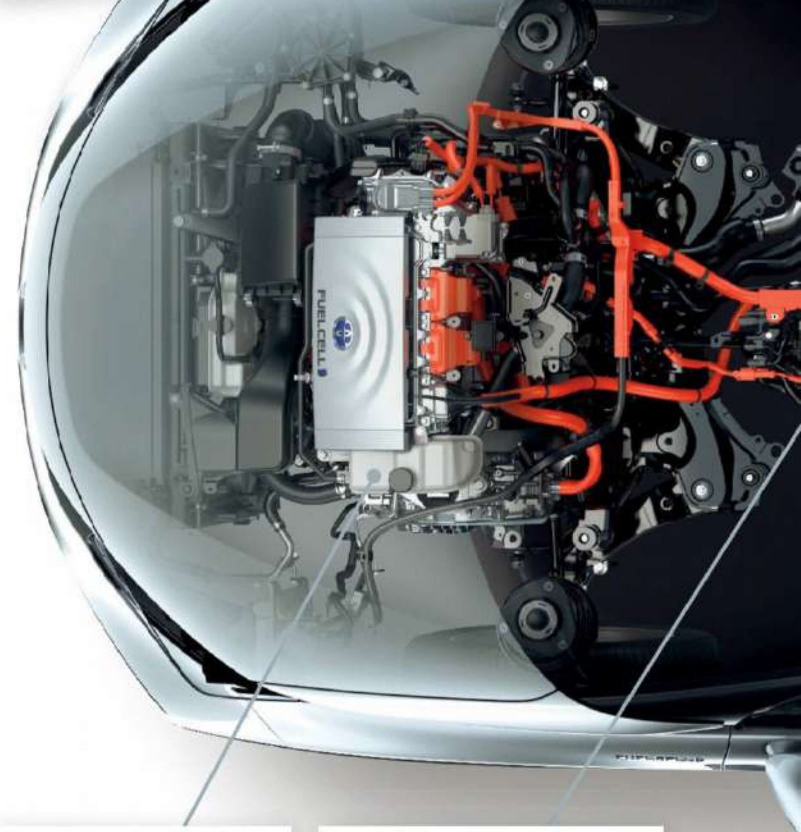
But the bad news is significant. Hydrogen can be efficient, but lots of fossil fuels are currently used to create hydrogen – and that undermines everything. That will have to change if hydrogen is to become viable, but biomass, solar, wind and other renewable sources are being developed.

There are also questions around efficiency elsewhere. Positively, however, the US Department of Energy estimates that conventional petrol engines run at around 20 per cent efficiency, while hydrogen fuel cell engines are between 40 and 60 per cent efficient. That's great, but more energy is required to compress, transport and store hydrogen, and renewable methods used to produce hydrogen may not always be very efficient.

There's not much in terms of infrastructure, either, with only around 20 filling stations in the UK. At least 100 will be needed to provide the bare minimum of national coverage. If you want a stark comparison, consider that there are more than 37,500 electric charging points across the UK. While hydrogen fuel cells are an exciting option, there's still a long road ahead.

© Getty

Filling stations need to be built for hydrogen, or existing facilities need to be refurbished



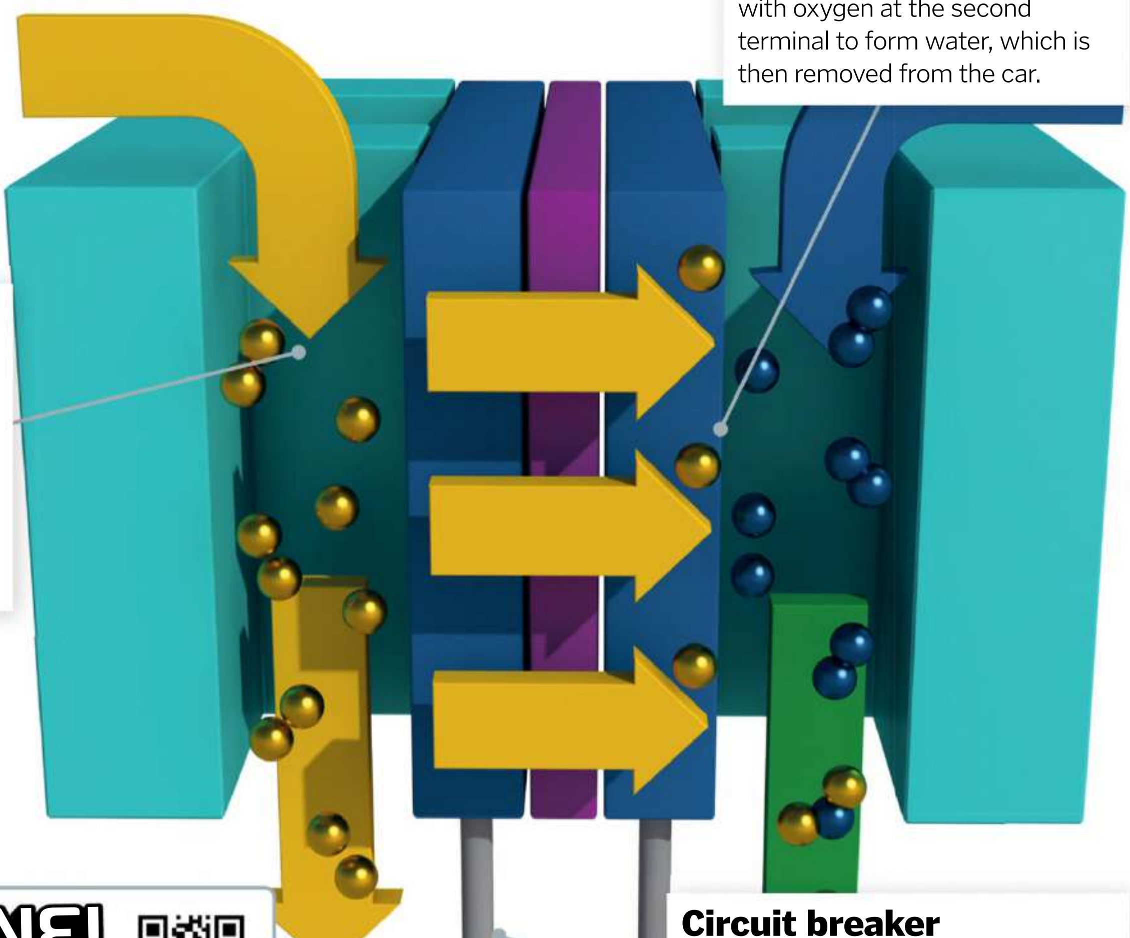
Motoring along
Motors used by hydrogen cars are often the same as those in battery-powered vehicles – the power method is just different.

Creating a current
The converter changes the fuel cell's high-voltage electricity to a lower voltage that the car can use.

Play it cool
Heat is produced by fuel cells, so air flows through the front of the car to keep everything chilled.

Fuel cells explained

Here's how hydrogen fuel cells work and how they function inside new cars



A positive outcome
Electrons and protons combine with oxygen at the second terminal to form water, which is then removed from the car.

Separate charges
Hydrogen is separated into protons and electrons at a terminal called the anode, and a catalyst accelerates the process.

Circuit breaker
Negatively charged electrons flow through a circuit, generating electricity that is used to power the motor.

© Illustration by Adrian Mann

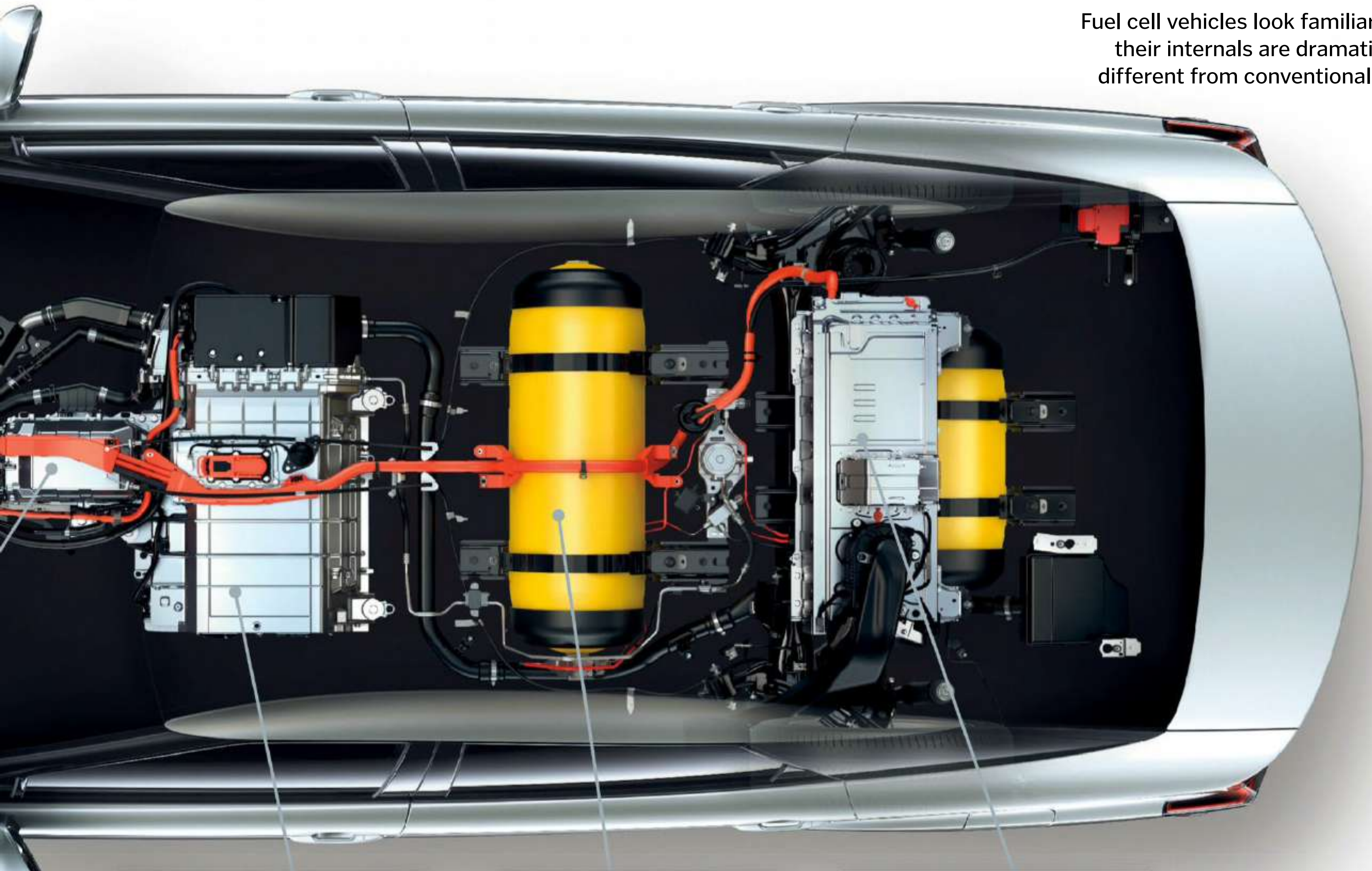
AR ZONE! SCAN HERE

© Getty

Fuel cells started life in laboratories, but this futuristic technology is powering cars

Fuel cell vehicles look familiar, but their internals are dramatically different from conventional cars

© Toyota

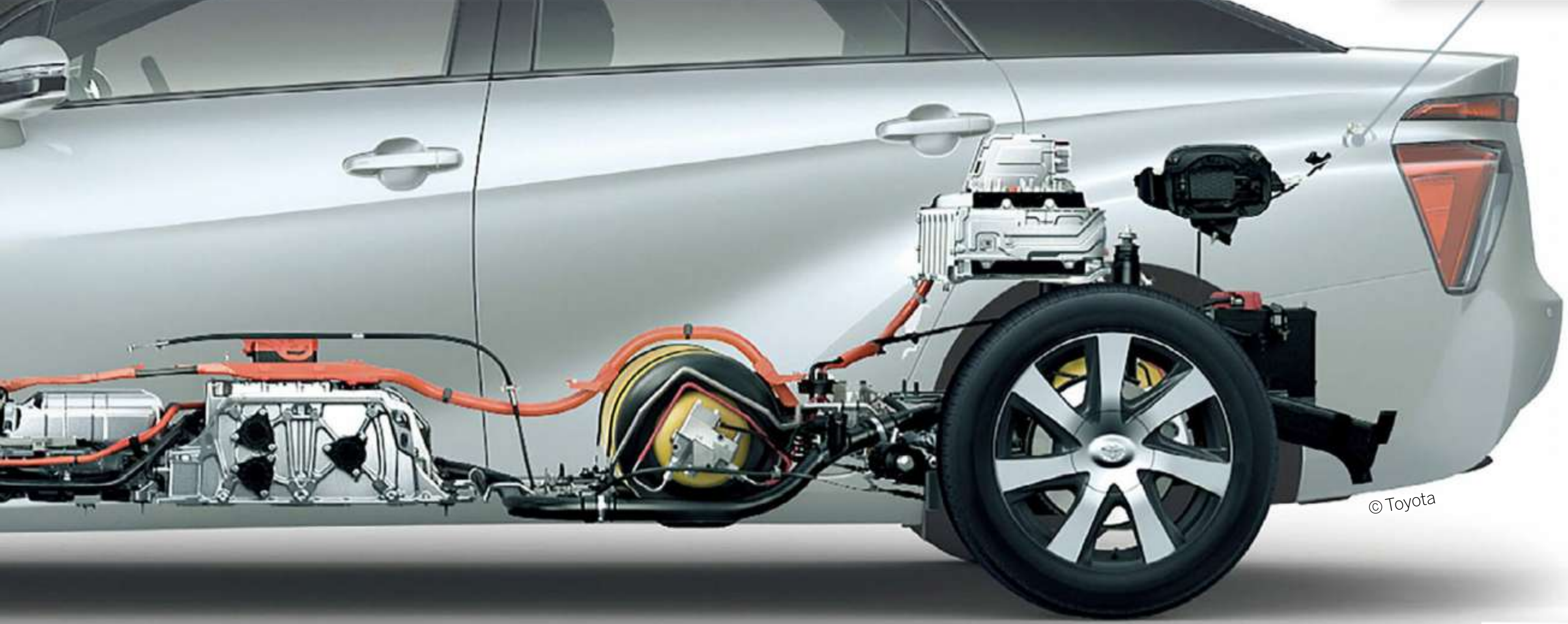


Stacked up
Fuel cells are small, so they're arranged in stacks that provide combined power – the latest Toyota Mirai uses 330 cells.

Strong tanks
Compressed hydrogen is stored here until it's needed. Hydrogen is explosive, so these have to be very strong.

Storing up
A nickel-metal hydride battery assists the fuel cell stack during acceleration, and stores energy from deceleration.

Gas-guzzler
Filling the tank is easy – the nozzle establishes a seal to maintain pressure, and it takes about five minutes to fill.



© Toyota

5 FACTS ABOUT
THE HEADY WORLD OF HYDROGEN

1 **Early beginnings**
The first hydrogen fuel cell charging station opened in Swindon in 2011 at Honda's manufacturing site. It served the FCX Clarity, Honda's first hydrogen car.

2 **Lighter than air**
Hydrogen fuel cells aren't just used in cars – they've been used in space rockets, and they could be used to power buildings, trucks and even planes.

3 **Filling the gaps**
The UK may need more hydrogen infrastructure, but other areas of the world are doing better – there are dozens of filling stations in California, with over 100 more to be built by 2027.

4 **Heavy lifting**
It's estimated that more than 53,000 hydrogen fuel cell vehicles were being used globally by the end of 2020, including around 31,000 forklift trucks.

5 **Big-name involvement**
Mercedes produced the first road-legal fuel cell car in 1998, BMW is developing a concept SUV and Jaguar is aiming to produce a Range Rover that uses fuel cells.

A lot of hot air?

Just two hydrogen-powered cars are sold in the UK, and they're both pricey – the Hyundai NEXO and Toyota Mirai cost more than £60,000 ($83,850). Despite that, a handful have been sold. The Metropolitan Police, the National Trust and a major rental car company have already added some to their fleets. Some bus fleets also use hydrogen fuel cell vehicles.

Toyota expects its cars to cost the same as its hybrid models by 2025. Elsewhere, BMW and a dozen other companies have committed to $10 billion (£7 billion) worth of investment in the next decade, and Toyota reckons that every major car manufacturer will soon be working on hydrogen-based hardware. Experts think that hydrogen gaining ground is inevitable: it'll have to play a part if the UK government is going to meet its pledge to make the country carbon-neutral by 2050, and we've already got a great natural infrastructure for generating hydrogen.

© Toyota

The Toyota Mirai is available in the UK, but it can only be filled at a handful of stations

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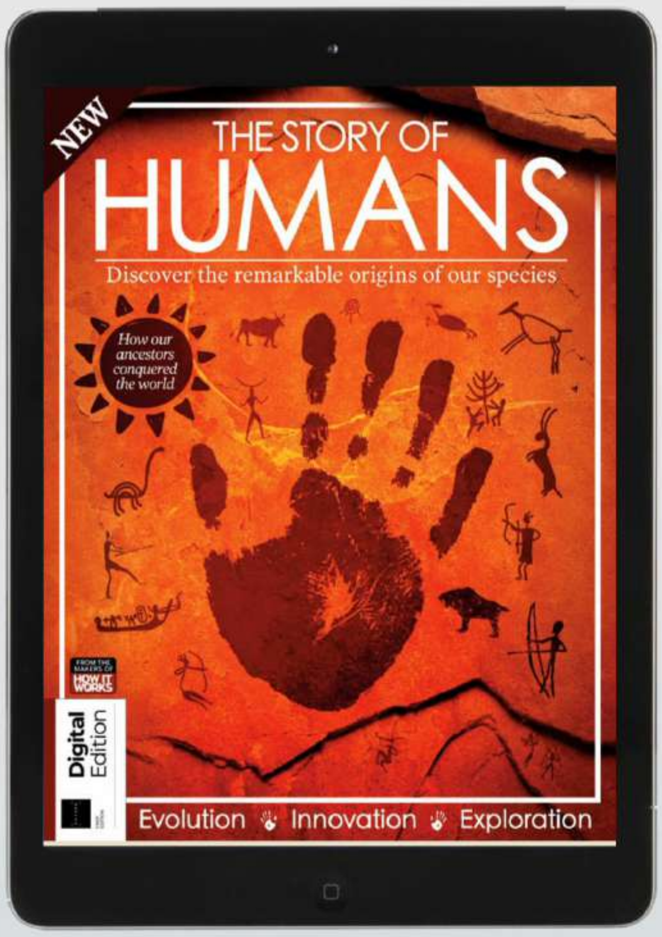

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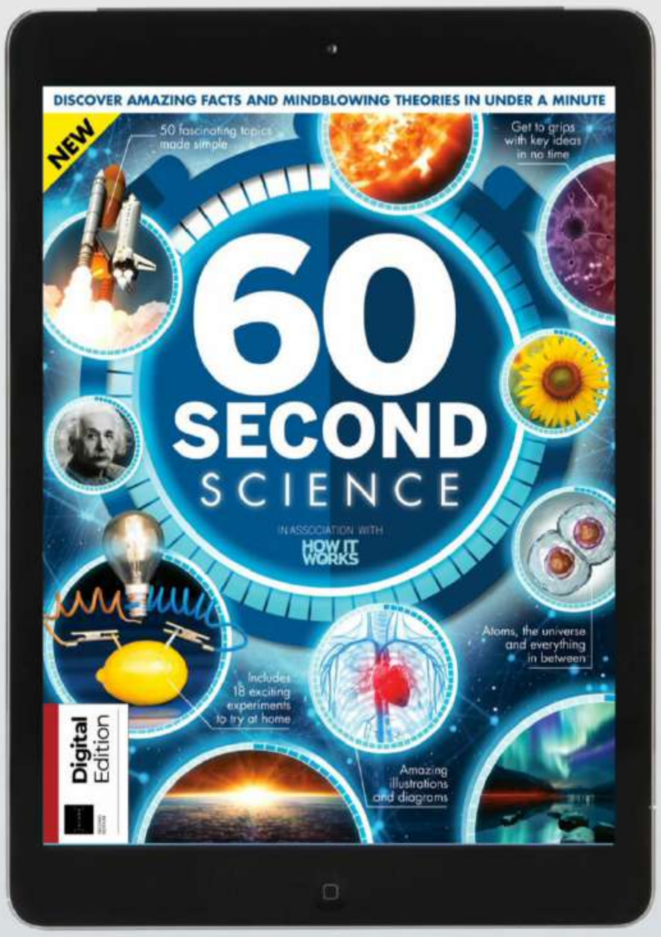

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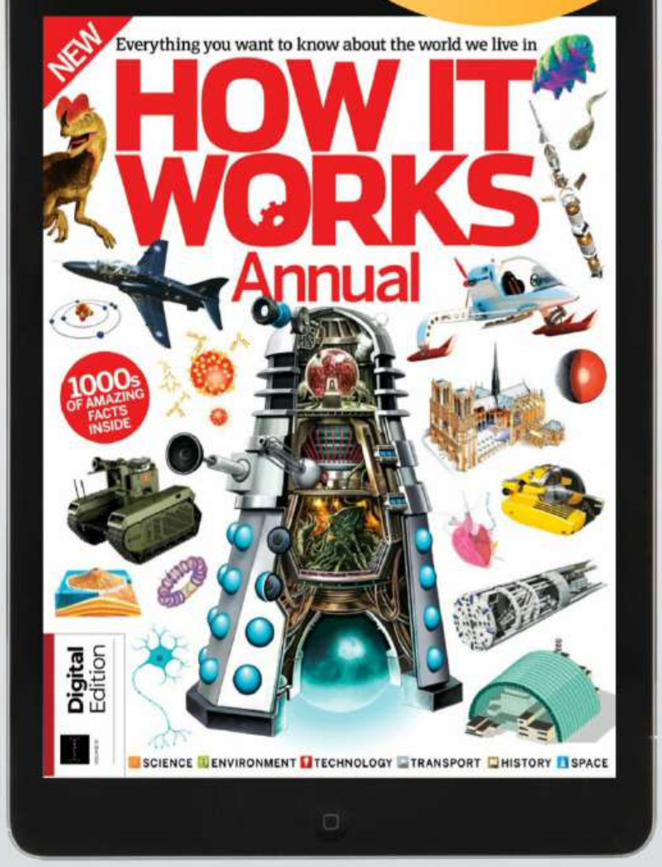

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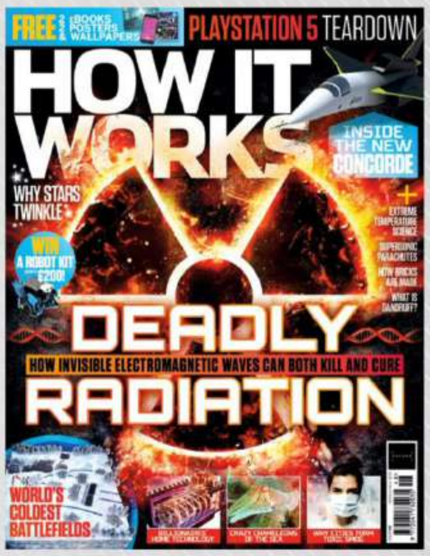
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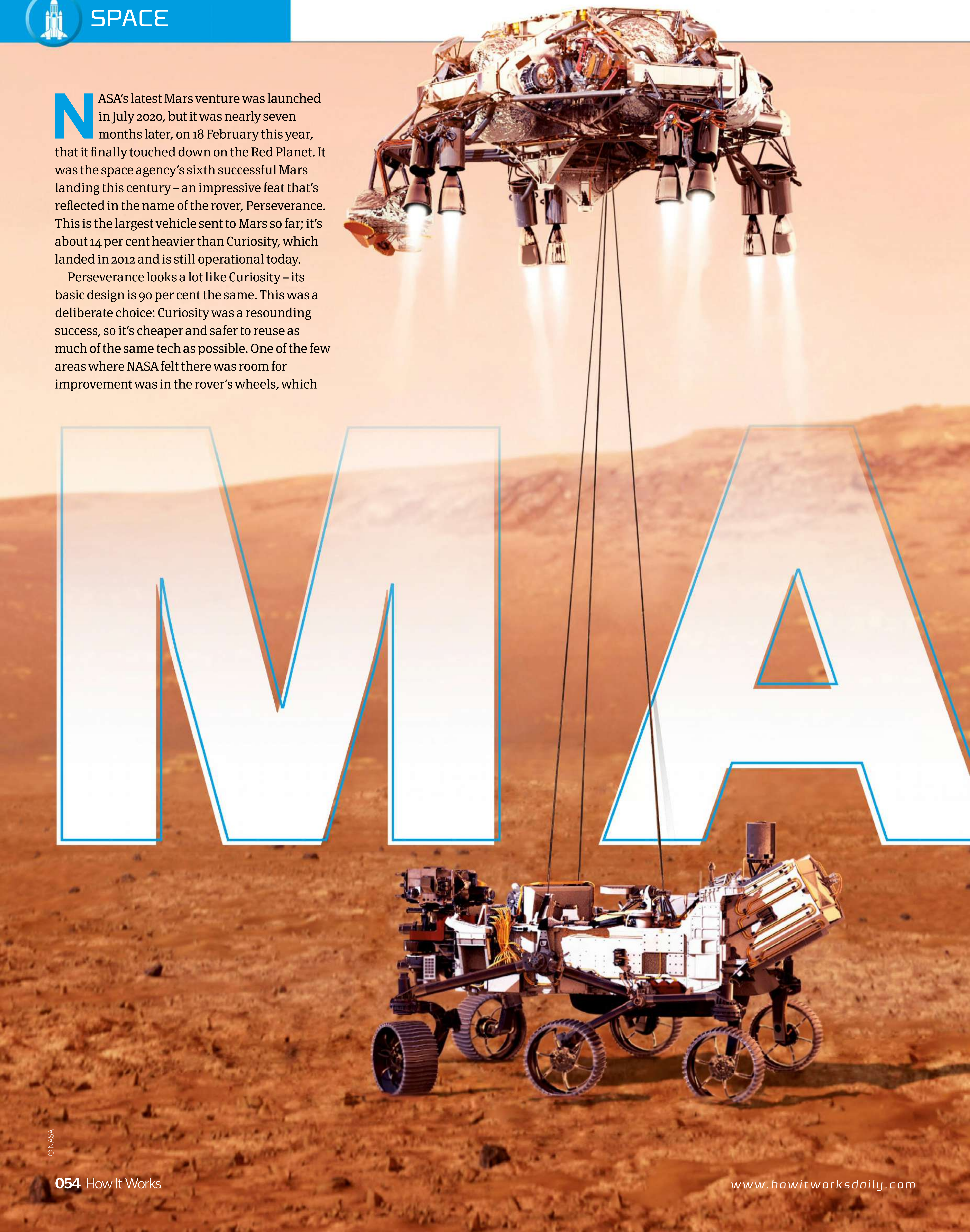
MA

NASA's latest Mars venture was launched in July 2020, but it was nearly seven months later, on 18 February this year, that it finally touched down on the Red Planet. It was the space agency's sixth successful Mars landing this century – an impressive feat that's reflected in the name of the rover, Perseverance. This is the largest vehicle sent to Mars so far; it's about 14 per cent heavier than Curiosity, which landed in 2012 and is still operational today.

Perseverance looks a lot like Curiosity – its basic design is 90 per cent the same. This was a deliberate choice: Curiosity was a resounding success, so it's cheaper and safer to reuse as much of the same tech as possible. One of the few areas where NASA felt there was room for improvement was in the rover's wheels, which



© NASA

DID YOU KNOW? *Jezero crater, which was filled with water in the distant past, takes its name from a Slavic word for lake*

receive a considerable battering from the Martian terrain. Perseverance has a new set of wheels, made from the same material but with thicker skin and a different tread pattern.

When Curiosity arrived at Mars in 2012, it used a previously untested 'sky crane' landing technique, being winched down to the surface while the rocket-powered descent stage hovered at an altitude of about 20 metres. As complicated as this sounds, it's actually much simpler than a design in which the whole descent stage lands and deploys the rover from the surface. Unsurprisingly Perseverance also employed the sky crane technique – but with a twist.

With all previous Mars landings, safety has been the top priority, so landing sites were chosen to be as flat and featureless as possible. Curiosity landed in the first safe spot it found. But Mars 2020 was designed to explore a very specific location of scientific interest, which happens to be just the opposite of flat and featureless. In order to land safely in a rougher landscape than its predecessors, it employed a new technique called Terrain Relative Navigation. The descending spacecraft looked at the ground below and compared this to a map with suitable landing sites marked on it, as well as various hazards such as steep slopes and large boulders.

23
Number of cameras carried by Perseverance

The team celebrates a successful landing on the Red Planet's surface

RS 2020

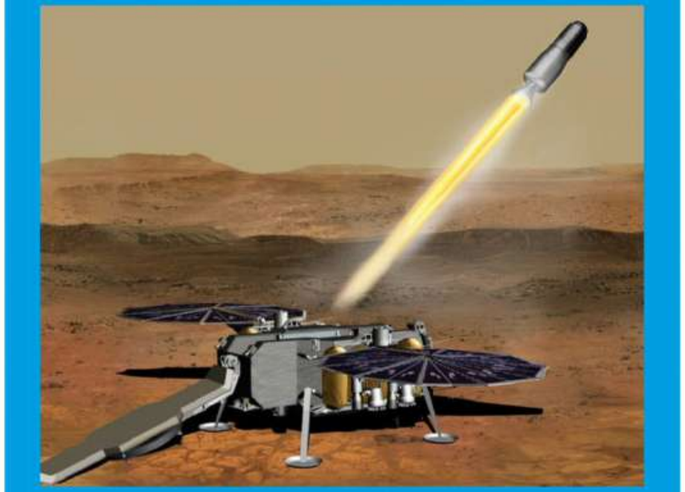
THE BOLDEST MISSION YET TO THE RED PLANET FEATURES THE PERSEVERANCE ROVER AND INGENUITY HELICOPTER

Words by **Andrew May**

All images © NASA

Mars sample return

Like its predecessor Curiosity, Perseverance has an onboard chemical laboratory to analyse rock samples as it goes along. But it has a new trick up its sleeve as well. It can seal and store some of the samples so they can subsequently be studied back on Earth. The idea is that the rover will leave these samples at strategic points, where they will remain for several years until they are collected by another rover on a future mission. This rover will blast the samples into Mars orbit, where they will be passed to another spacecraft for return to Earth.



One-way cached samples could be fired back into Mars orbit by a future mission

If it found itself heading for one of these hazards, it could divert to the nearest safe landing spot.

Everything worked the way it was supposed to, and Perseverance touched down safely in the designated target area, close to the western rim of the 28-mile-wide Jezero crater, which over 3 billion years ago was filled with water. It was fed by a number of rivers that broke through the crater rim, one of which left signs of an ancient river delta. It's close to this delta that Perseverance landed – and that's the key to its scientific mission.

Previous landers have established that Mars once had all the necessary ingredients to support microbial life, but they didn't look for traces of those ancient life forms themselves. Perseverance will do exactly that. The delta site was chosen because on Earth, the mud at the bottom of a delta is perfect for concentrating and preserving organic material, which might still be found in rocks there today. The rocks higher up, at the edge of the crater, may contain fossilised 'pond scum' that constitutes direct evidence of microscopic life.

With so much work to do, Perseverance is carrying a lot of scientific equipment – that's why it's noticeably heavier than Curiosity. The rover is loaded with cameras, many of them for practical things like navigation and hazard avoidance, but the most powerful are for the science mission. As well as a high-resolution panoramic camera similar to the one on Curiosity, the mast on Perseverance also carries a new instrument called SuperCam. This instrument can fire a laser beam at rocks up to seven metres away, vaporising part of the surface and allowing the rock's composition to be analysed spectroscopically.

While its cameras allow Perseverance to study rocks from a distance, it can also get up close to collect rock samples using its robotic arm. A few of the samples will be stored for subsequent return to Earth, but others will be examined in-situ with instruments mounted on the arm itself. These can make a detailed analysis of chemical composition using X-rays and ultraviolet (UV) light.

The mission involves a number of firsts for Mars, including a ground-penetrating radar to look for hidden subsurface features such as the remains of ancient lava flows or sand dunes.

That's related to Perseverance's main science mission, but two other pieces of novel tech have more to do with demonstrating possibilities for the future. There's the aptly named Ingenuity helicopter, as well as a system called MOXIE that can produce pure oxygen from carbon dioxide in the Martian atmosphere. The size of a car battery, MOXIE works a bit like a tree, inhaling CO_2 and exhaling oxygen. There won't be much of it, but future human missions to Mars will need a source of oxygen, and the technology used in MOXIE could be scaled up to provide that.

Seven minutes

Time from entry into Mars' atmosphere to landing

A computer animation showing how the Perseverance rover will deploy the Ingenuity helicopter on Mars

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FLYING ON MARS

While many space probes have descended through the Martian atmosphere to the surface, sustained powered flight is another matter. Aircraft on Earth are able to fly by using aerodynamic lift to counteract gravity. The amount of lift generated depends on several factors, including the density of the surrounding air, the size of the aircraft's wings – or rotors in the case of a helicopter – and the speed at which air flows over the wings or rotor blades. Flight on Mars is intrinsically difficult due to the ultra-low atmospheric density at ground level – only a hundredth of its value on Earth. Fortunately, that's compensated to some extent by the weaker Martian gravity – only a third as strong as Earth's – so less lift is required in the first place. Even so, NASA's Ingenuity helicopter needs much larger and faster rotating rotor blades than a drone of similar mass on Earth.

© Getty

NASA's Mars objectives

Determine whether life ever existed on Mars

Focusing on an area that looks like it may once have had conditions favourable to microbial life, Perseverance will look for preserved biosignatures in rocks that formed in those ancient times.

Characterise the Martian climate

Studying the past climate of Mars also tells us about the possibility of ancient life there. To this end, the rover's instruments will search for evidence of ancient habitable environments.

Characterise the geology of Mars

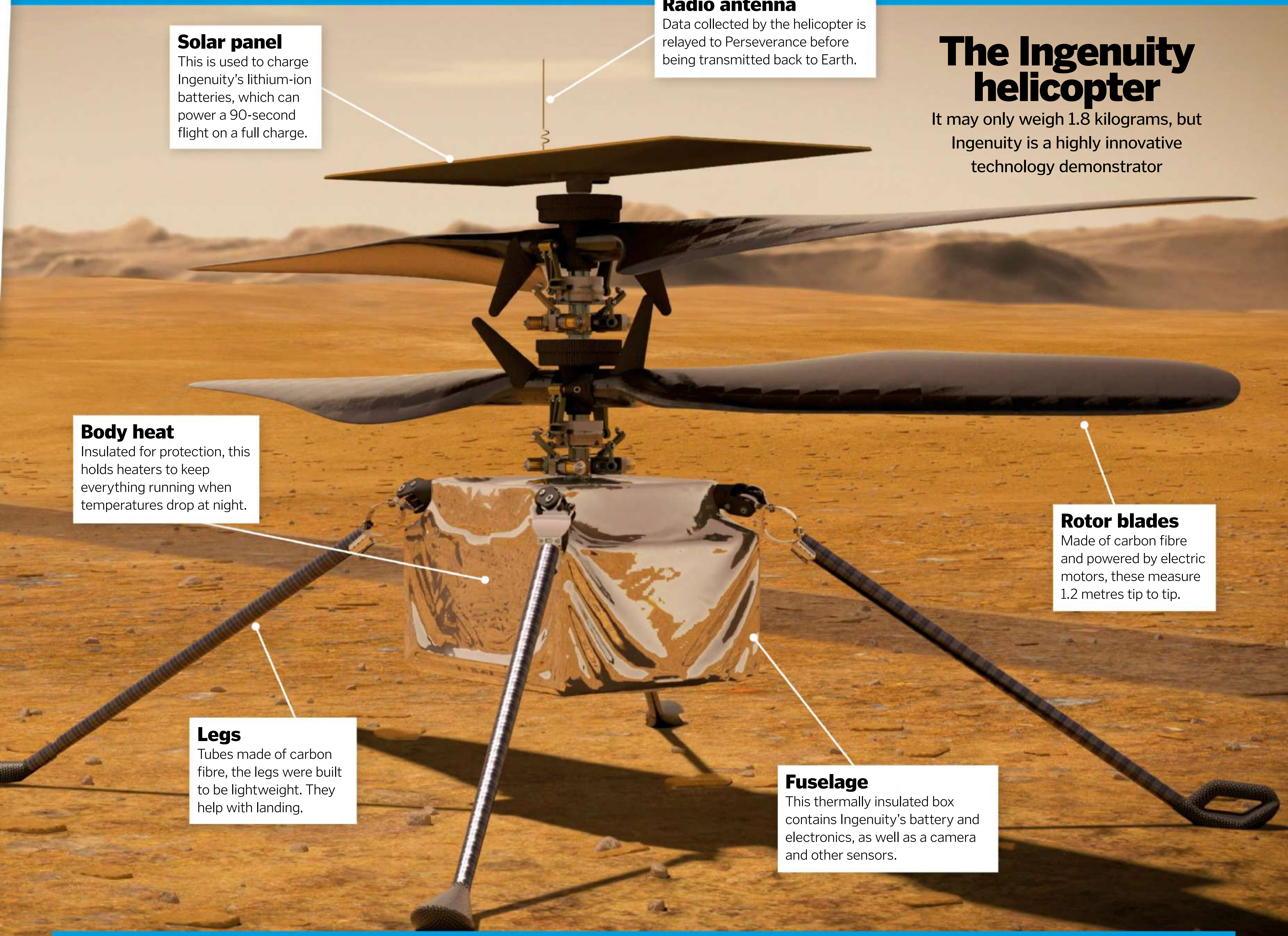
Perseverance will study the rock record to learn about the geological processes that moulded the Martian landscape, particularly looking for rocks that formed in water – one of the essential prerequisites of life.

Prepare for human exploration

With an eye on future visits by human travellers, Perseverance will try out methods of utilising natural resources for life support, as well as monitoring environmental conditions to inform future mission planning.

The Ingenuity helicopter

It may only weigh 1.8 kilograms, but Ingenuity is a highly innovative technology demonstrator



Radio antenna
Data collected by the helicopter is relayed to Perseverance before being transmitted back to Earth.

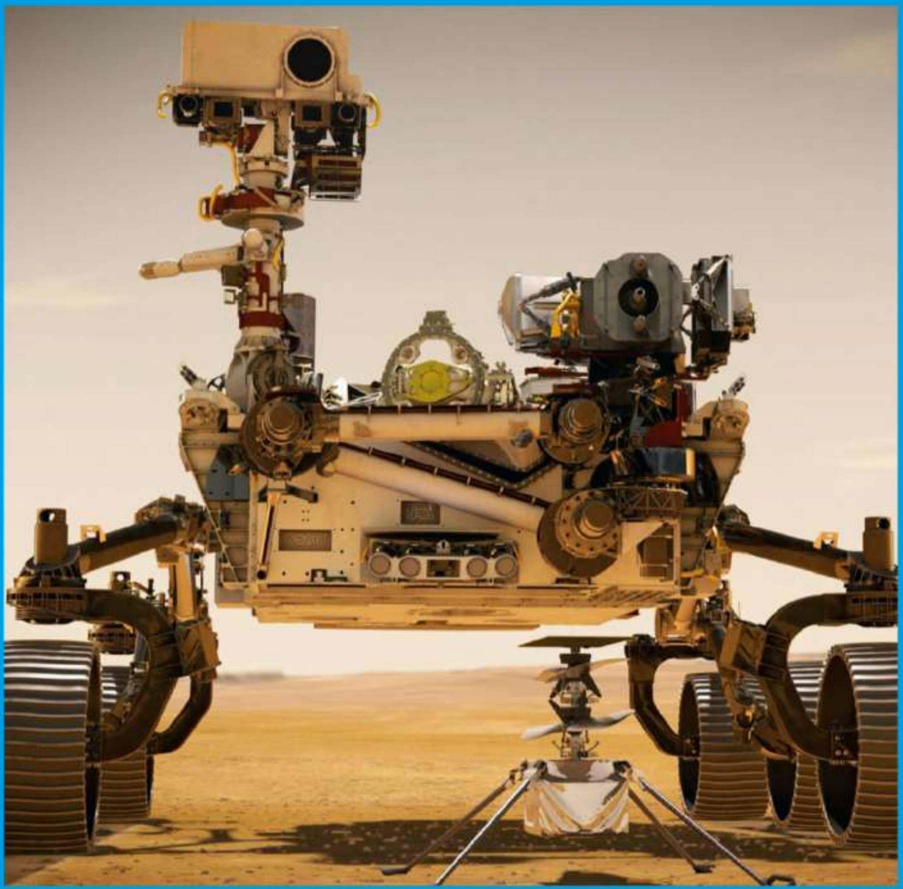
Solar panel
This is used to charge Ingenuity's lithium-ion batteries, which can power a 90-second flight on a full charge.

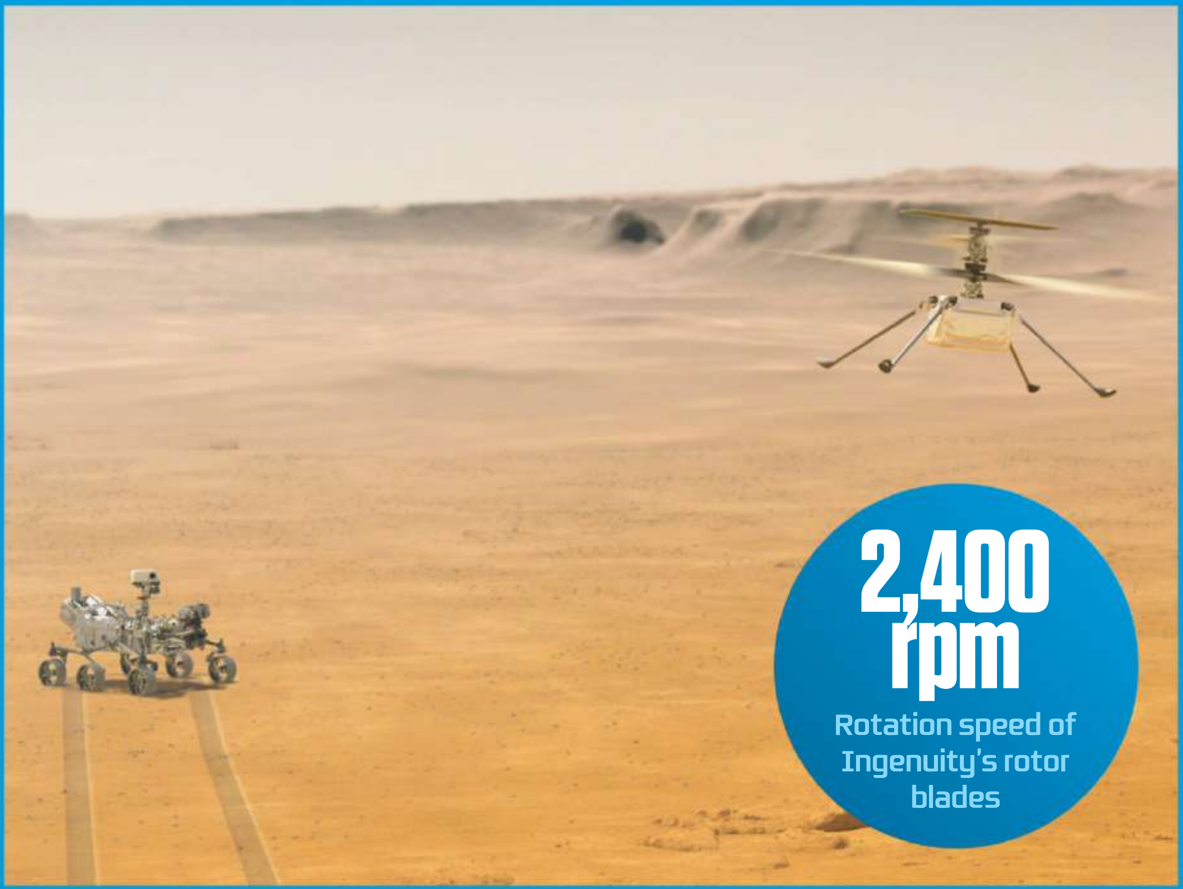
Body heat
Insulated for protection, this holds heaters to keep everything running when temperatures drop at night.

Rotor blades
Made of carbon fibre and powered by electric motors, these measure 1.2 metres tip to tip.

Legs
Tubes made of carbon fibre, the legs were built to be lightweight. They help with landing.

Fuselage
This thermally insulated box contains Ingenuity's battery and electronics, as well as a camera and other sensors.





2,400 rpm
Rotation speed of Ingenuity's rotor blades

All images © NASA

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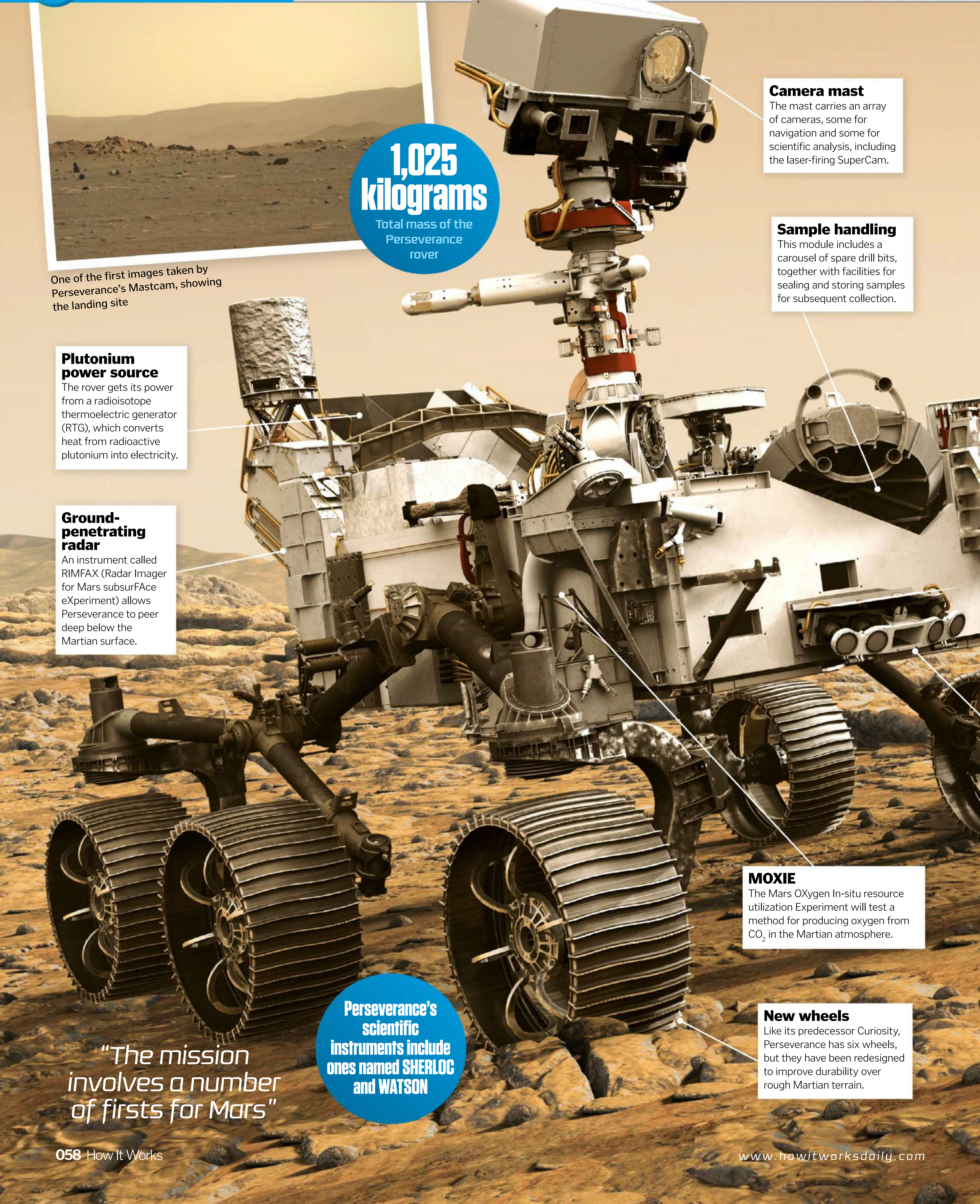
One of the first images taken by Perseverance's Mastcam, showing the landing site

1,025 kilograms

Total mass of the Perseverance rover



Camera mast

The mast carries an array of cameras, some for navigation and some for scientific analysis, including the laser-firing SuperCam.

Sample handling

This module includes a carousel of spare drill bits, together with facilities for sealing and storing samples for subsequent collection.

Plutonium power source

The rover gets its power from a radioisotope thermoelectric generator (RTG), which converts heat from radioactive plutonium into electricity.

Ground-penetrating radar

An instrument called RIMFAX (Radar Imager for Mars subsurFAce eXperiment) allows Perseverance to peer deep below the Martian surface.

MOXIE

The Mars OXygen In-situ resource utilization Experiment will test a method for producing oxygen from CO_2 in the Martian atmosphere.

New wheels

Like its predecessor Curiosity, Perseverance has six wheels, but they have been redesigned to improve durability over rough Martian terrain.

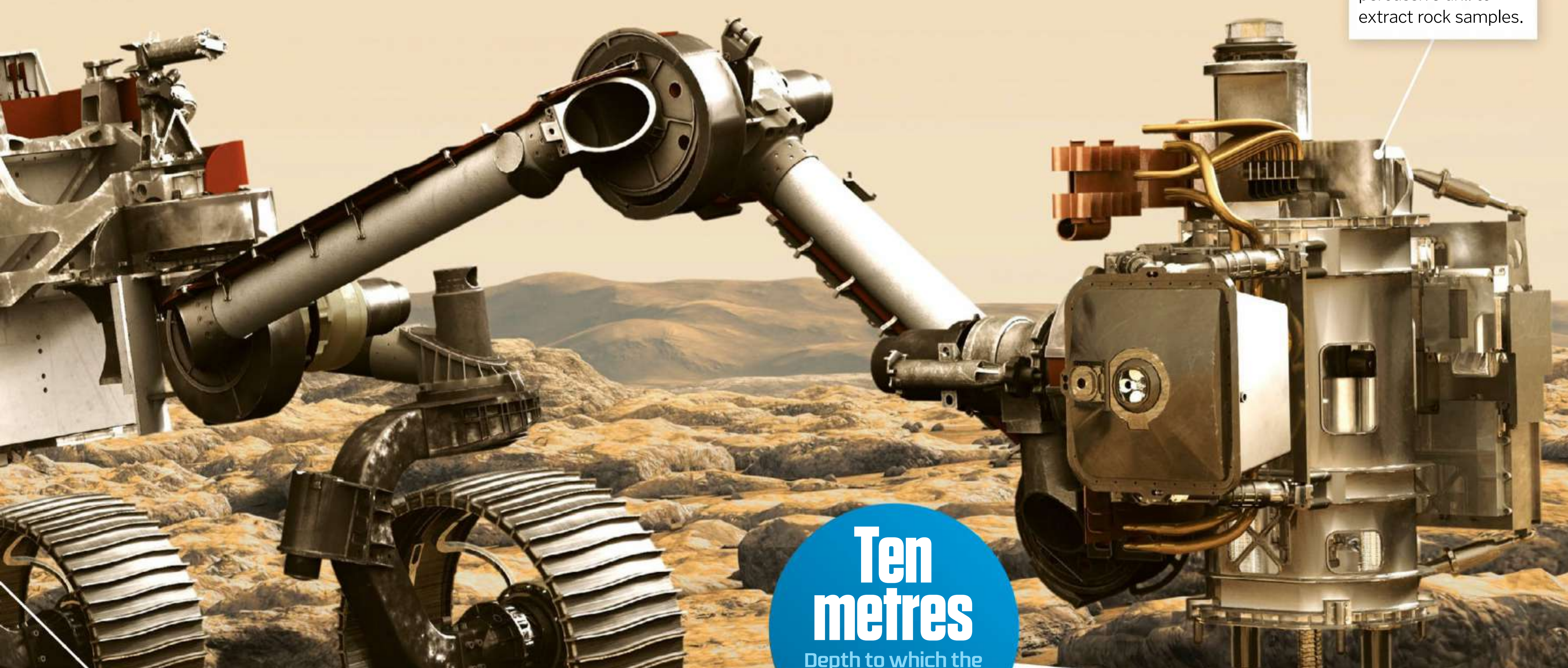
Perseverance's scientific instruments include ones named SHERLOC and WATSON

> "The mission involves a number of firsts for Mars"

DID YOU KNOW? *Perseverance carries a meteorite fragment from London's Natural History Museum as a calibration target*

THE PERSEVERANCE ROVER

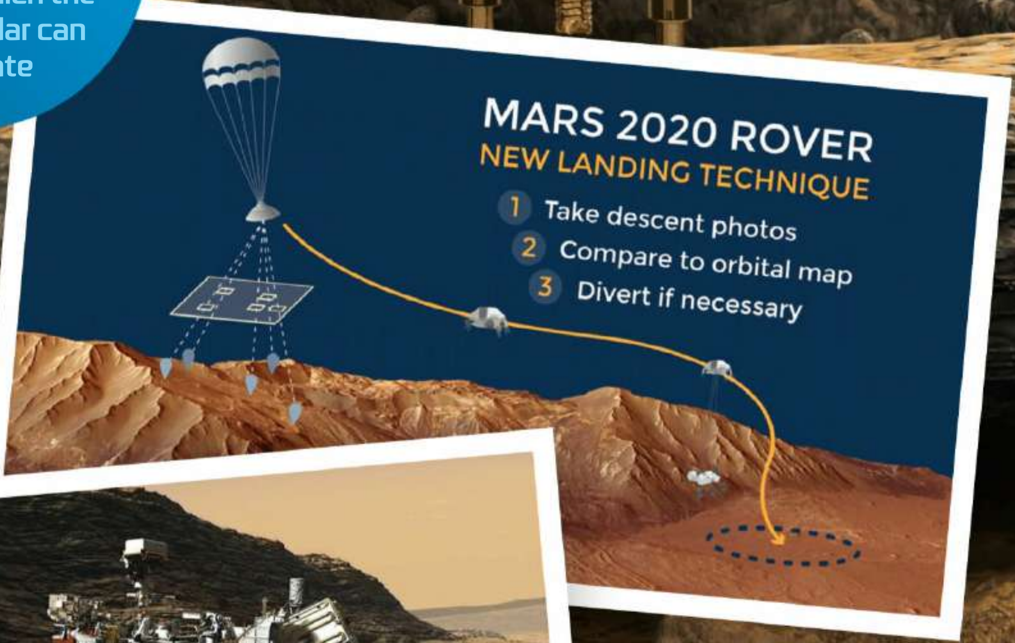
BRISTLING WITH SCIENTIFIC INSTRUMENTS, THE LATEST ROBOT EMISSARY TO MARS IS THE MOST SOPHISTICATED YET



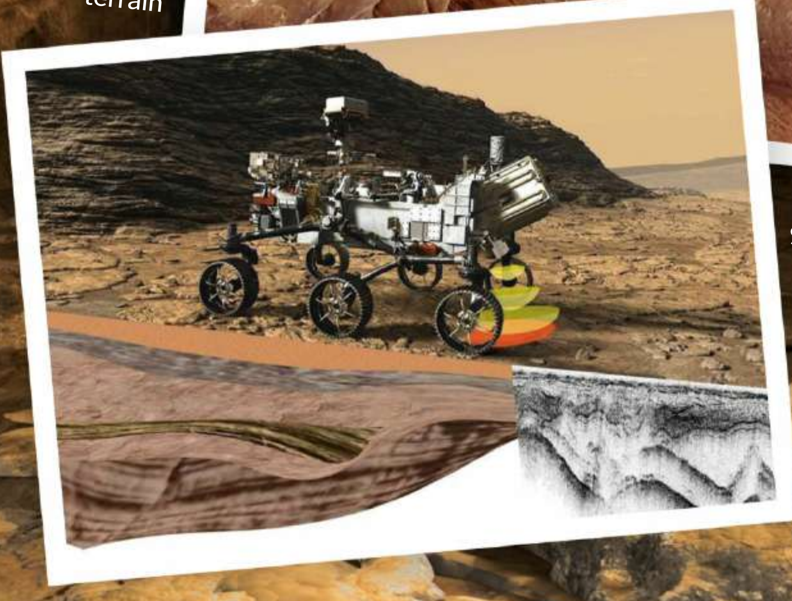
Robotic arm
The two-metre-long arm carries various scientific instruments as well as a rotary percussive drill to extract rock samples.

Hazard-avoidance cameras
Because communications are too slow for Perseverance to be driven by controllers on Earth, it requires 'Hazcams' to avoid obstacles.

Ten metres
Depth to which the RIMFAX radar can penetrate


MARS 2020 ROVER
NEW LANDING TECHNIQUE
1 Take descent photos
2 Compare to orbital map
3 Divert if necessary

Unlike previous landers, Mars 2020 was able to divert away from hazardous terrain



Schematic illustration of the way subsurface structure will be revealed by the RIMFAX radar

All images © NASA

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How to identify a galaxy

Hubble's 'tuning fork' sorts a bewildering variety of galaxies into a small number of basic types

Astronomers have studied thousands of galaxies, and they all look slightly different. But certain basic features crop up again and again, and these repeating features can be used to classify galaxies into different types. The first person to do this was Edwin Hubble in 1926, soon after it was first established that galaxies are 'island universes' outside our own Milky Way.

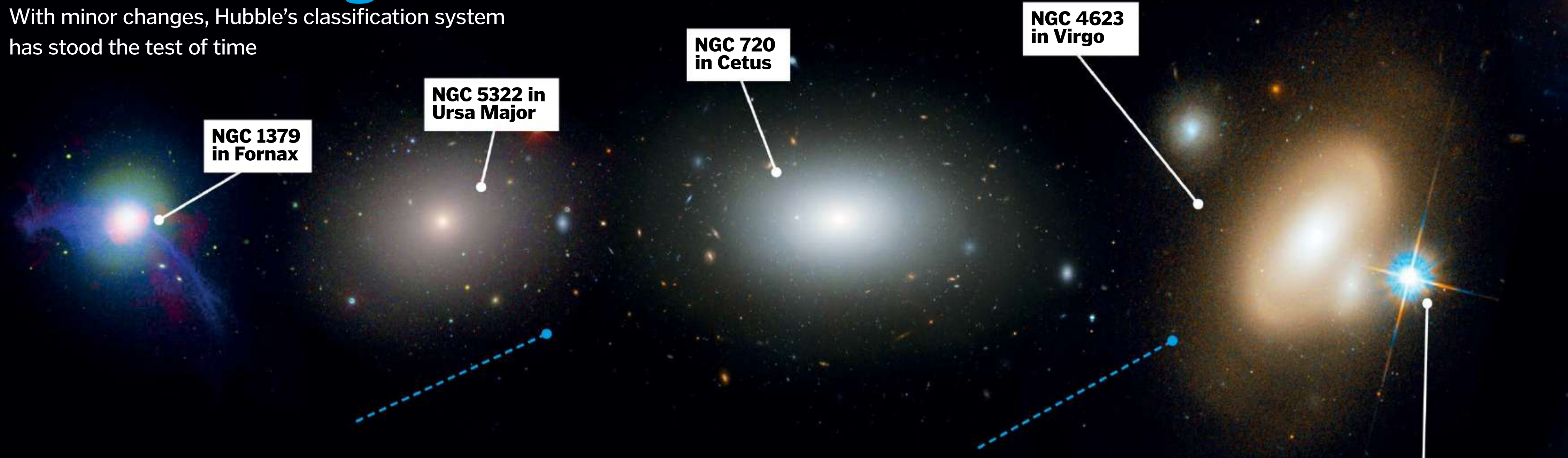
Hubble did this purely on the basis of appearance, so there are many things we know now that Hubble was unaware of. Radio astronomy, for example, has shown us the distribution of otherwise invisible gas, while high-resolution spectroscopic measurements provide information on stellar motions and chemical composition.

Nevertheless, the broad classification system devised by Hubble has survived these new discoveries. As a first cut, galaxies can be divided into two types: elliptical and spiral. Elliptical galaxies are relatively featureless, dominated by old stars that wander round on a random jumble of orbits, with the galaxy as a whole showing little net rotation. Generally ellipticals contain hardly any gas, and as a consequence, very few new stars are formed in them. Spiral galaxies, on the other hand, are full of gas and young stars, with abundant star formation going on in the spiral arms that give them their name. Both the stars and gas tend to move on near-circular orbits in a thin, rapidly rotating disc.

About half of all spiral galaxies show a bar-like structure spanning the central region. Hubble classified these 'barred spirals' in a parallel sequence to the ordinary spirals, giving a characteristic 'tuning fork' shape to his classification system. The same system is still used by astronomers today, often with various tweaks and additions to reflect more recent discoveries.

Hubble's tuning fork

With minor changes, Hubble's classification system has stood the test of time



ELLIPTICAL GALAXIES

In Hubble's system, these are designated E0 to E7 depending on how flattened they appear in photographs. E0 looks almost spherical, while E7 is a much more elongated shape. This doesn't necessarily reflect the galaxy's real shape, though. A cigar-shaped galaxy seen end on, for example, would be classified as E0.

LENTICULAR GALAXIES

Even before de Vaucouleurs, Hubble's student Allan Sandage introduced another intermediate type between ellipticals and spirals, which he designated S0 and referred to as 'lenticular galaxies'. These are disc-shaped like spirals, but they resemble ellipticals in having very little gas or star formation, and lack spiral arms.

Galactic evolution

Hubble referred to ellipticals as 'early type' galaxies and spirals as 'late type'. This is sometimes misinterpreted to mean that he believed there was an evolutionary sequence from elliptical to spiral. He actually meant the opposite. Based on the ages of the stars in them, the ellipticals we see are older – in other words they originated earlier – than spirals. Hubble was implying an evolutionary sequence in which spirals come first and ellipticals later. Although a complete theory of galactic evolution is still lacking, there seems to be some truth to this. Many ellipticals are believed to be the result of two or more spiral galaxies colliding and merging with each other. The initial product may be quite chaotic, but after a while it will settle down to a stable configuration with randomised orbits and less gas – in other words, looking very much like an elliptical galaxy.

NGC 3921 is a merging pair of disc galaxies which may become a single elliptical

© ESA/Hubble

DID YOU KNOW? *NASA scientists estimate that the observable universe contains at least 2 trillion galaxies*

Irregular galaxies

One thing all the galaxies in the Hubble sequence – spiral or elliptical – have in common is that they are almost symmetrical in appearance. But some galaxies – as many as a quarter of them – don't fit into this sequence at all. Referred to as irregular galaxies, these tend to be small in size, with around a tenth the mass of our own Milky Way. Irregular galaxies are similar in composition to spirals, with plenty of gas and young stars, but they lack well-defined spiral arms and they are often distinctly asymmetric in shape.

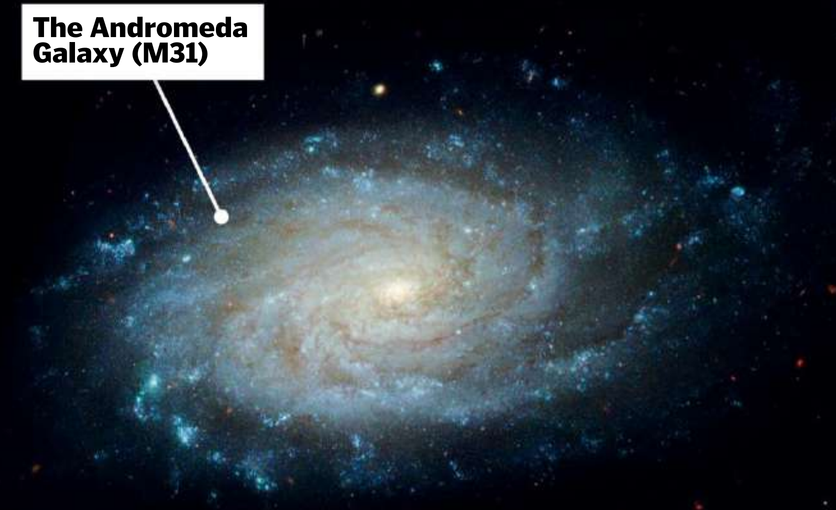
© NASA/Hubble

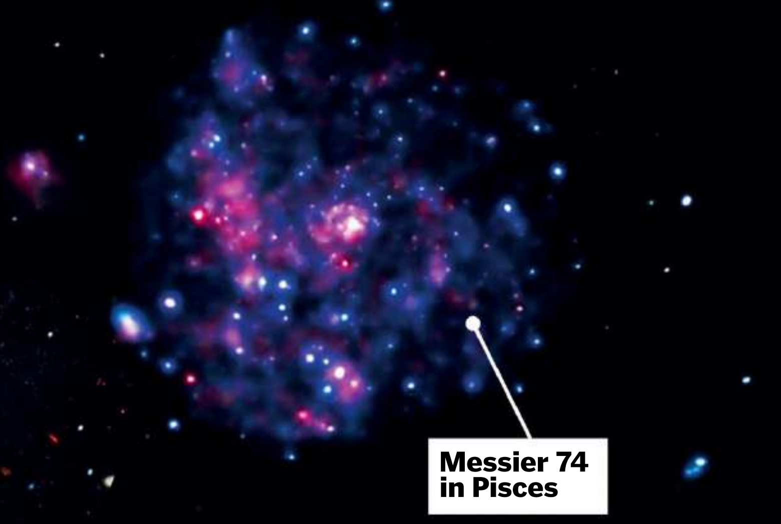
NGC 4449 in Canes Venatici is a nice example of a small irregular galaxy

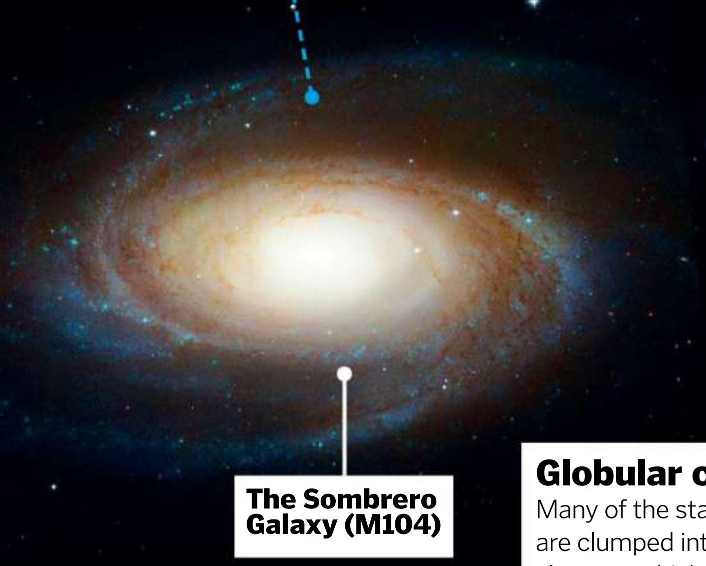
> "The classification system devised by Hubble has survived new discoveries"

SPIRAL AND BARRED SPIRAL GALAXIES

Hubble referred to tightly wound spirals as Sa, less tight spirals as Sb and loose spirals as Sc. Similarly, barred spirals follow a sequence from SBa to SBc. In both cases the size of the central bulge, resembling a tiny elliptical galaxy, decreases along the sequence from a to c.

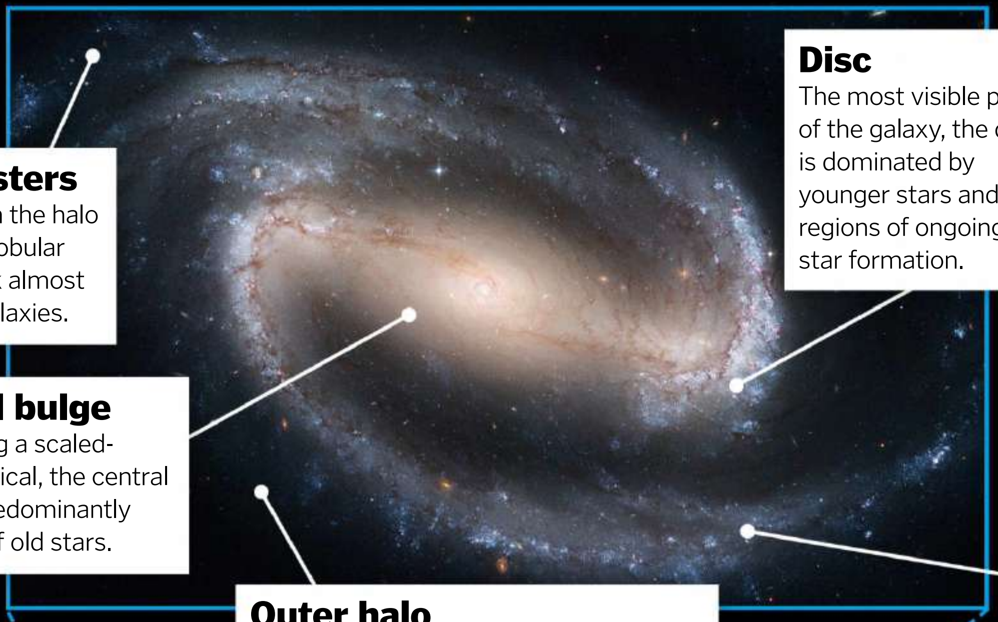

The Andromeda Galaxy (M31)


Messier 74 in Pisces


The Sombrero Galaxy (M104)

ANATOMY OF A SPIRAL GALAXY

Spiral galaxies, such as our own Milky Way, have several distinct components



Globular clusters
Many of the stars in the halo are clumped into globular clusters, which look almost like miniature E0 galaxies.

Central bulge
Resembling a scaled-down elliptical, the central bulge is predominantly made up of old stars.

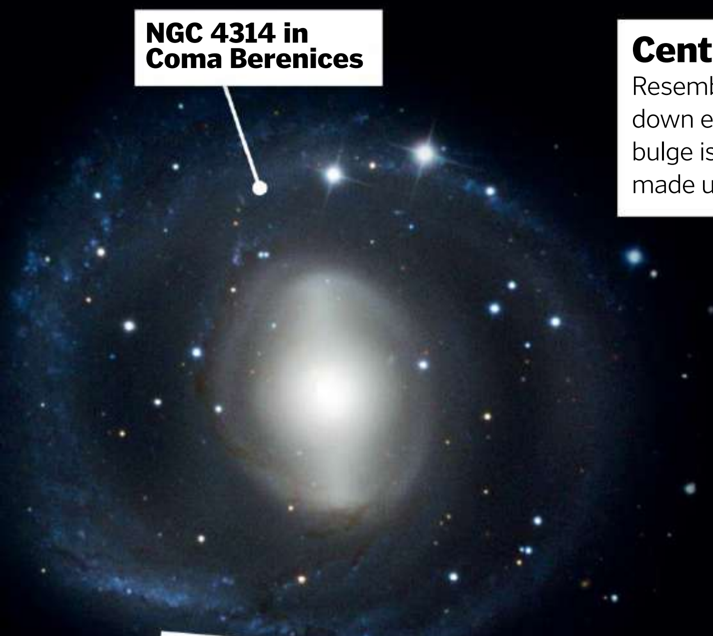
Outer halo
The whole galaxy is enveloped by a large, roughly spherical halo, containing relatively faint, very old stars.

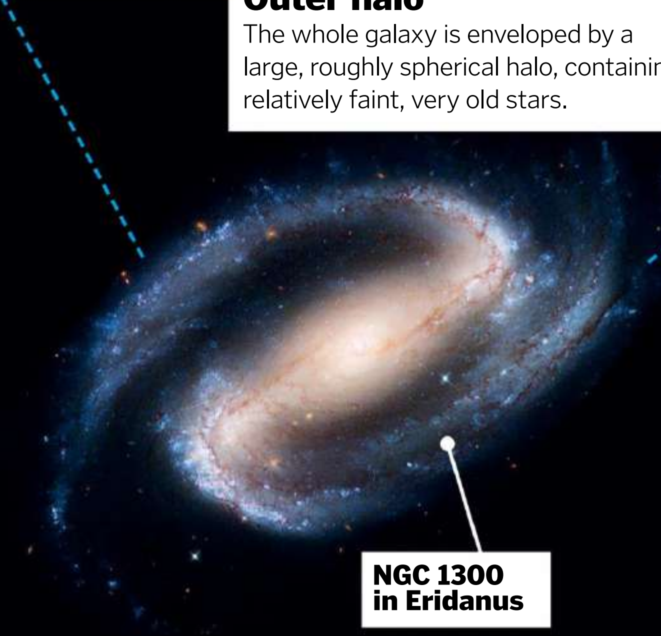
Disc
The most visible part of the galaxy, the disc is dominated by younger stars and regions of ongoing star formation.

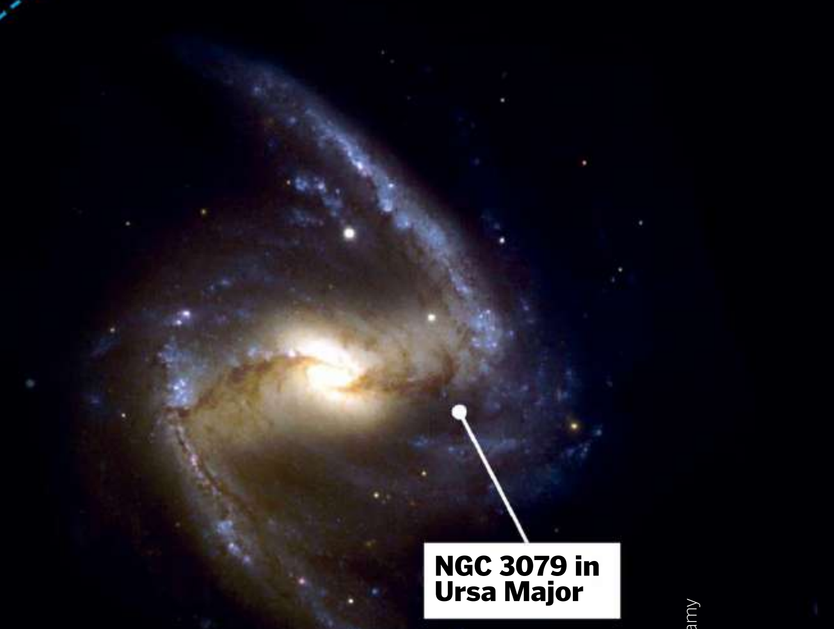
Spiral arms
The characteristic spiral pattern is the disc's most prominent feature, and this is where our Sun is located in the Milky Way.

INTERMEDIATE GALAXIES

Later researchers, such as the French astronomer Gérard de Vaucouleurs, realised that Hubble's tuning fork diagram doesn't do justice to the full variety of galaxy shapes. He developed a more complicated system that introduces an intermediate type between spirals and barred spirals, which he designated SAB.


NGC 4314 in Coma Berenices


NGC 1300 in Eridanus


NGC 3079 in Ursa Major

© Alamy

Edwin Hubble, the originator of the 'tuning fork' system of galaxy classification

Source: Wiki/Johan Hagemeyer

NASA's rocket hub

Take a look inside the Vehicle Assembly Building, where spacecraft prepare for liftoff

The Saturn V rocket was built with the intention of sending humans to the Moon, and became successful in doing so when launching several of the historic Apollo missions into space. At 111 metres tall, it set a record at the time for being the largest rocket ever made. In order to successfully prepare and assemble such a huge engine, NASA decided to create a suitably sized building that could safely house and assemble spacecraft and their premanufactured modules. Construction started in 1963, and the building was completed in 1966.

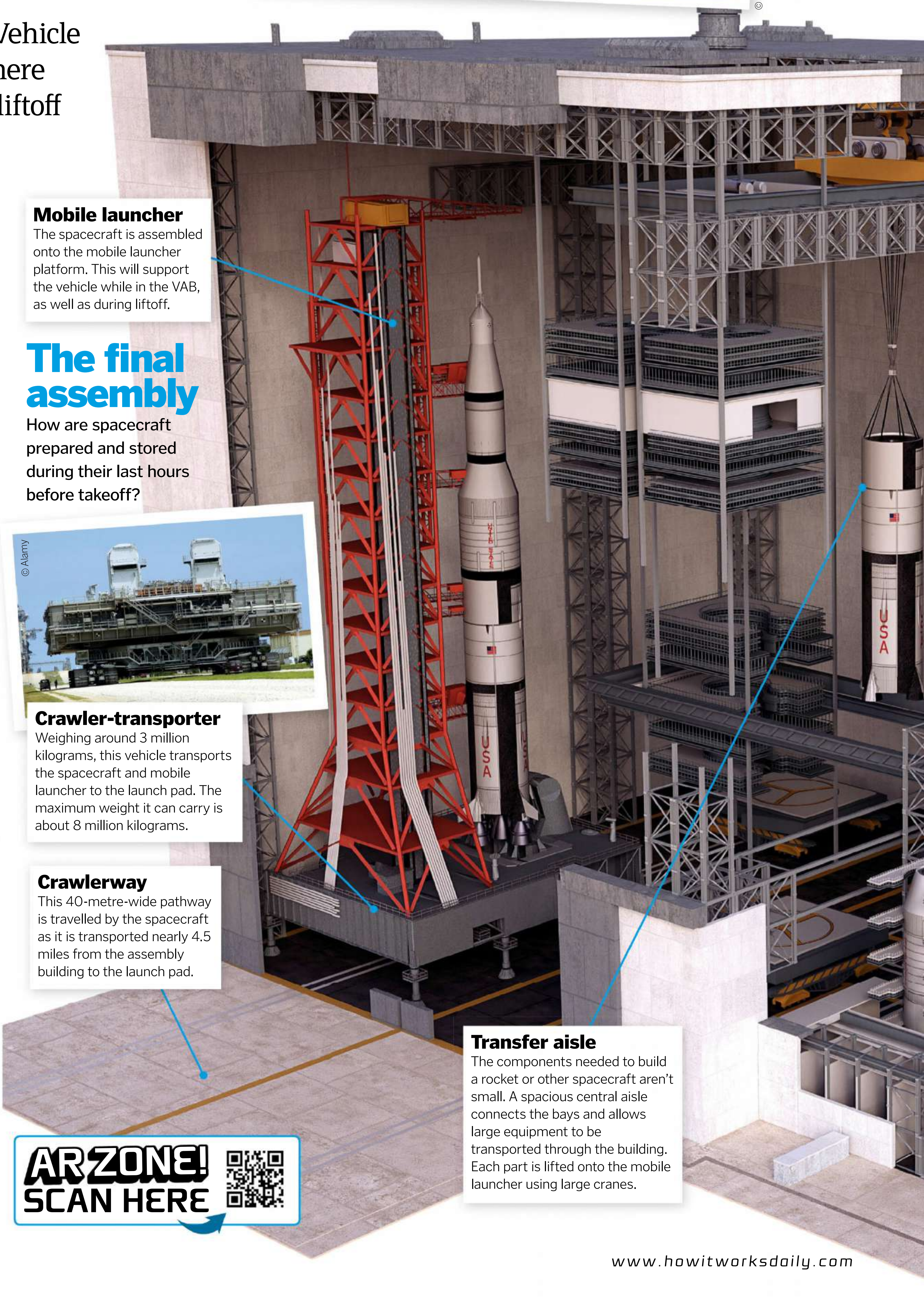
To store many heavy rockets and other substantial spacecraft components in one place, the building needs to be strong. To support the structure, there are huge steel posts placed every six metres along the base. These reach down over 50 metres into the solid limestone rock below. Also, the heavy floors are made of 30 centimetres of reinforced concrete for added support.

Since its construction, NASA's Vehicle Assembly Building (VAB) has become America's prime location for assembling and housing rockets before takeoff. A rocket will take shape in the tallest sections of the building, its components carried by vehicles and by cranes. Surrounding the rocket, platforms are built to enable workers to stand close and analyse it from a variety of heights. When the big day arrives, having been inspected and reviewed inside the VAB, the spacecraft will undertake a six-hour journey as it is transported from the building to the launch pad.

© NASA/ Bill Whitev

The final assembly

How are spacecraft prepared and stored during their last hours before takeoff?



© Alamy

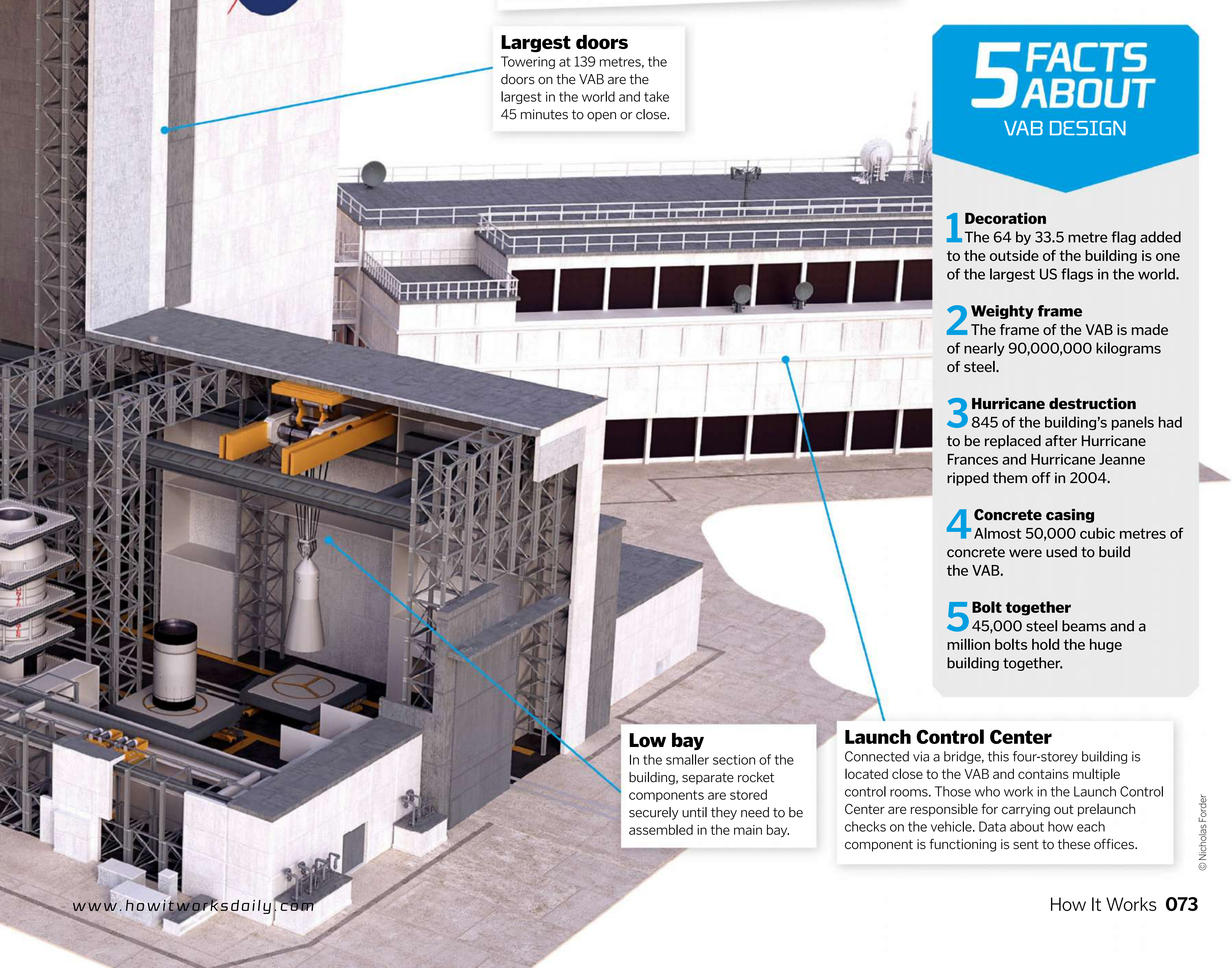
Mobile launcher
The spacecraft is assembled onto the mobile launcher platform. This will support the vehicle while in the VAB, as well as during liftoff.

Crawler-transporter
Weighing around 3 million kilograms, this vehicle transports the spacecraft and mobile launcher to the launch pad. The maximum weight it can carry is about 8 million kilograms.

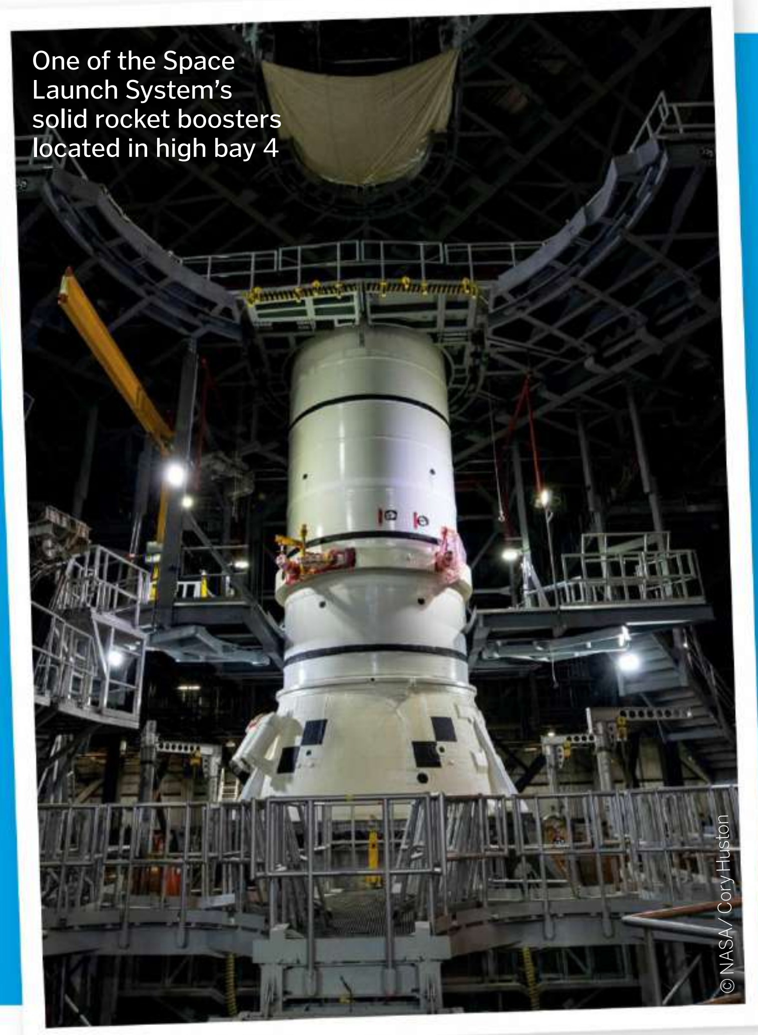
Crawlerway
This 40-metre-wide pathway is travelled by the spacecraft as it is transported nearly 4.5 miles from the assembly building to the launch pad.

Transfer aisle
The components needed to build a rocket or other spacecraft aren't small. A spacious central aisle connects the bays and allows large equipment to be transported through the building. Each part is lifted onto the mobile launcher using large cranes.

AR ZONE! SCAN HERE



High bay
The tallest section of the building is the high bay. Being 160 metres in height is necessary to allow rockets to be stored and moved in a vertical position. There are four high bays, two on the east and west sides of the building.



One of the Space Launch System's solid rocket boosters located in high bay 4

© NASA/ Cory Huston

What's being built now?

NASA is currently assembling the Space Launch System (SLS), a rocket that will carry the Orion spacecraft into space for the next human mission to the Moon. Inside the VAB, separate components are being built and assembled one by one onto the mobile launcher. This rocket will be used for the Artemis 1 mission, due to launch in November 2021. As the first of three planned missions, this will be uncrewed to test the rocket's performance and safety. The mobile launcher will remain in its current bay, with the SLS continuing to gain layers and being thoroughly analysed up until launch day. When the last piece is added, the SLS rocket will be taller than the Empire State Building as it stands inside the VAB bay.

Largest doors
Towering at 139 metres, the doors on the VAB are the largest in the world and take 45 minutes to open or close.

5 FACTS ABOUT VAB DESIGN

1 **Decoration**
The 64 by 33.5 metre flag added to the outside of the building is one of the largest US flags in the world.

2 **Weighty frame**
The frame of the VAB is made of nearly 90,000,000 kilograms of steel.

3 **Hurricane destruction**
845 of the building's panels had to be replaced after Hurricane Frances and Hurricane Jeanne ripped them off in 2004.

4 **Concrete casing**
Almost 50,000 cubic metres of concrete were used to build the VAB.

5 **Bolt together**
45,000 steel beams and a million bolts hold the huge building together.

Low bay
In the smaller section of the building, separate rocket components are stored securely until they need to be assembled in the main bay.

Launch Control Center
Connected via a bridge, this four-storey building is located close to the VAB and contains multiple control rooms. Those who work in the Launch Control Center are responsible for carrying out prelaunch checks on the vehicle. Data about how each component is functioning is sent to these offices.

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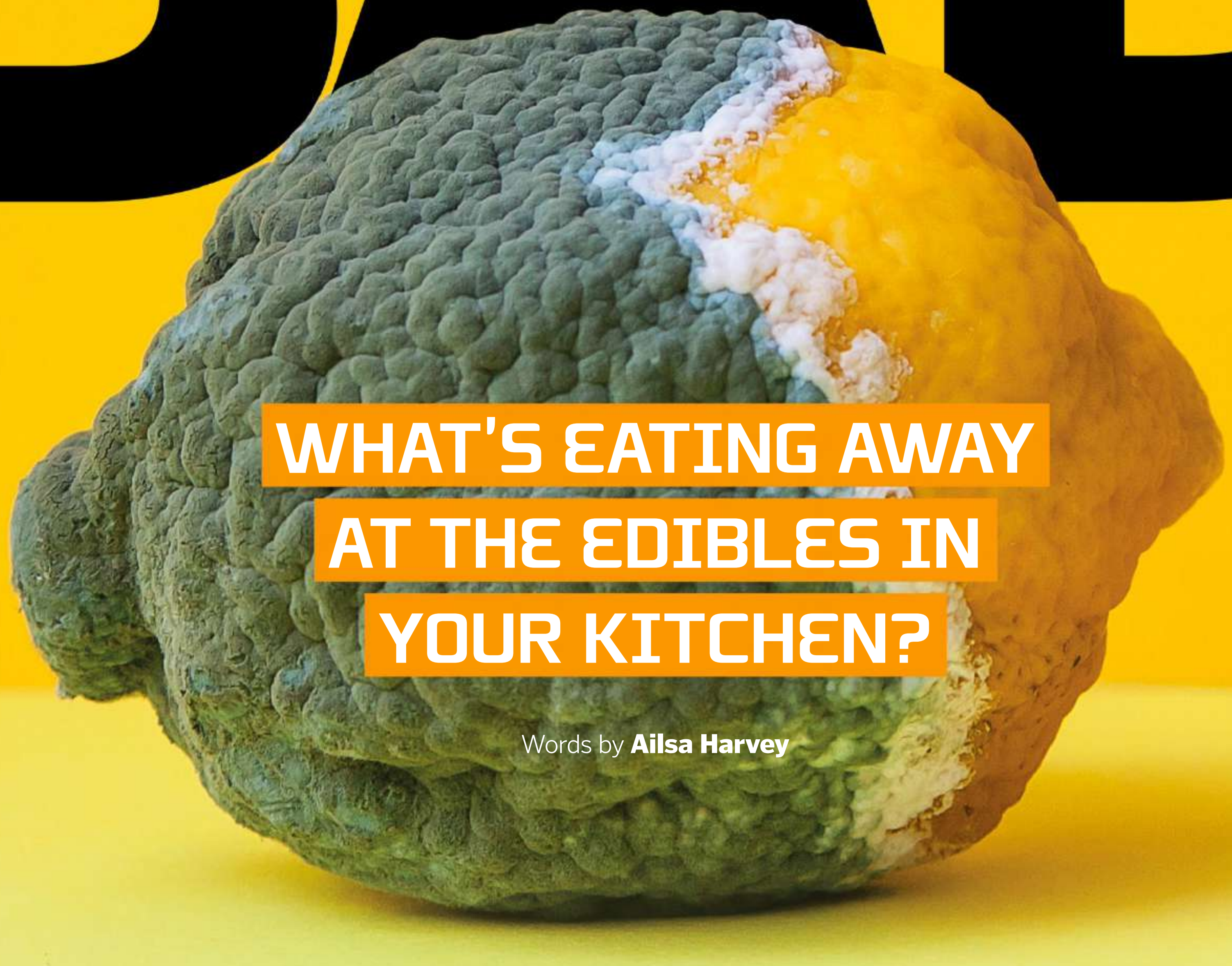
WHEN FOOD GOES BAD



WHAT'S EATING AWAY AT THE EDIBLES IN YOUR KITCHEN?

Words by **Ailsa Harvey**

Our lives revolve around food. As we fill up our cupboards with our weekly shopping and consume the shelves' contents multiple times a day, our favourite snacks only have a fleeting stay in our homes. Food is a permanent necessity, sustaining our health throughout our lives. But the shelf life of each item is remarkably temporary, giving our kitchens a high turnover rate.

On many airtight jars, it's suggested that you consume the entire contents within one week of opening it, and the freshest foods, such as fruits and vegetables, will remain so for an even shorter time period. The ingredients for our meals come with unique countdown clocks, and the timing for peak condition can sometimes be unpredictable. In order to fully understand the quality of each perishable food, you need to know the science behind their demise.

Food begins to rot when its cells die and break apart. The proteins inside leak out of these gaps and begin to eat away at the cells. Working from damaged ones to the healthier cells surrounding them, soon the entire piece of food will start to disintegrate. As bacteria and fungi join the feast and increase in numbers, their combined waste products add foul tastes and smells to the previously fresh food. Changes in appearance, odour and texture are all signs of decay.

Food spoilage is inevitable, but there are some ways you can slow this process down. Effective methods to prolong quality are used in food factories, as well as by consumers at home. Removing oxygen from packaging and sealing food until use stops air and microorganisms from compromising a food's freshness. Factories also heat treat many of their consumable products, as the majority of microorganisms can't withstand high temperatures.

© Getty

DID YOU KNOW? *Refrigerating bread slows mould growth, but causes it to go stale faster as starch molecules recrystallise*

WHAT CAUSES SPOILAGE?

FROM CREATURES TO CLIMATE, THESE ARE THE CULPRITS IN FOOD'S EXPIRATION

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ENZYMES

Enzymes are proteins that speed up some of foods' chemical reactions, and one of their purposes is to ripen fruits and vegetables. Enzymes don't just work to make food perfect for your palate, though, and they will continue to turn fruit from unripe, to ripe, to over-ripe. They are the reason your fruit continues to the disgustingly soft, squishy stage. When you bite into fruit, oxygen reaches the broken plant tissue. In apples, enzymes work quickly with this oxygen to produce compounds with a brown colour.

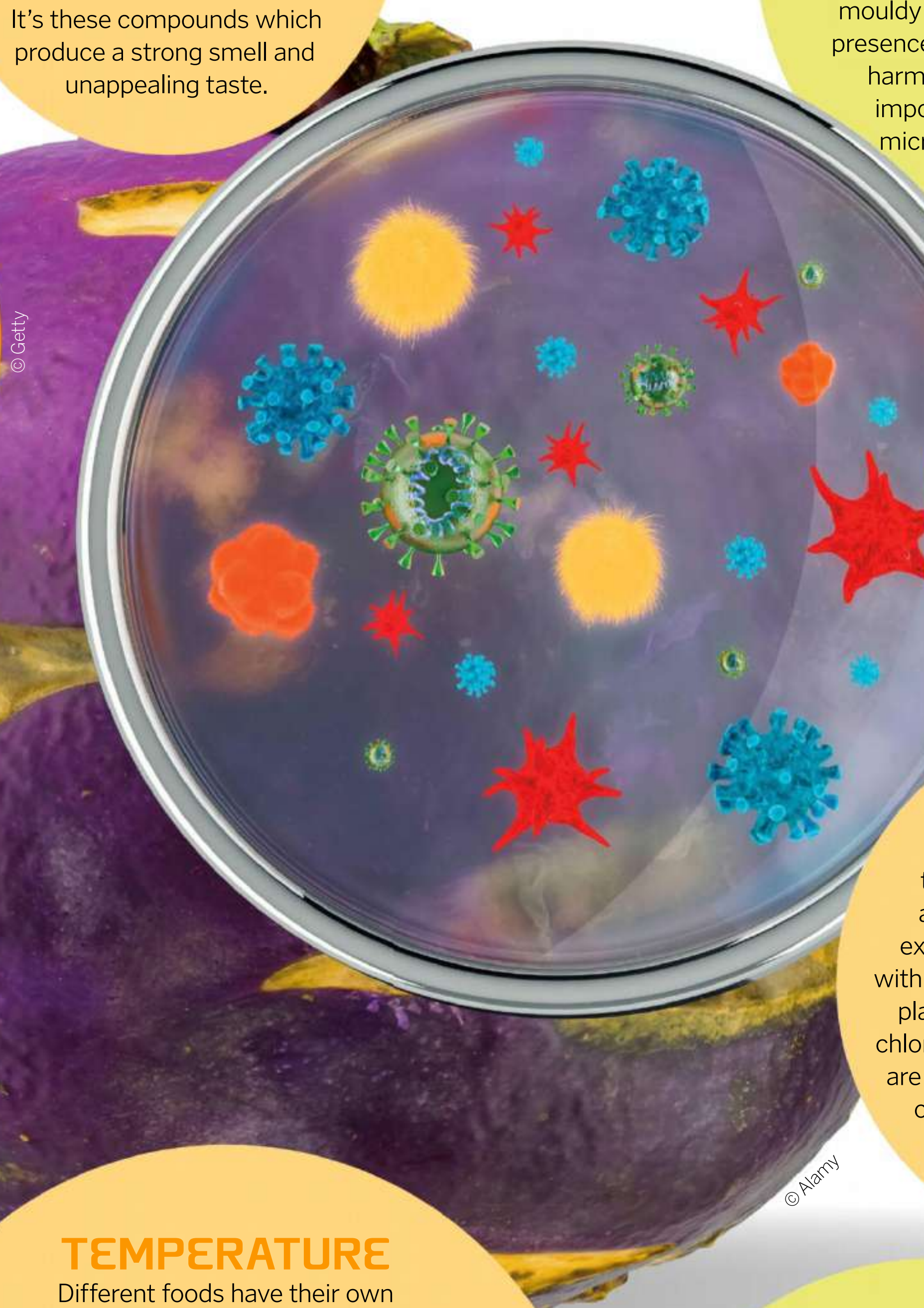
© Getty

AIR

21 per cent of air consists of oxygen, which can attack the fats in food. In fact, oxidation is the main cause of spoilage in fatty foods. When the fat oxidises, it forms smaller short-chain carbon compounds. It's these compounds which produce a strong smell and unappealing taste.

MICROORGANISMS

When bacteria and fungi grow in food, they can cause a change in colour, texture and smell. Many foods are not just desirable to us humans, but can also provide energy to these single-celled organisms. The microbial world is a diverse one. Some food growths create a green, mouldy appearance, clearly indicating the presence of fungi, while others can grow to harmful levels with zero visibility. It's important to remember that not all microbes are bad to consume, and some even hold health benefits.



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ANIMALS

Although we have designated some items as 'human food', they are not exclusively sought after by us. Other animals share the same tastes, and so in order to keep some fresh for ourselves, we need to store food away from animals like rodents, insects and parasites. When food is damaged by these creatures, it makes the deterioration process quicker, as well as increasing the likelihood of spreading disease.

© Getty

LIGHT

Food and drink are often covered in light-proof packaging to prevent photodegradation, the alteration of products due to light exposure. Some reactions that occur within foods require light for them to take place. Light can cause damage to the chlorophyll of fruit and vegetables. These are the cells that give some plants their colour. Over time this reaction can cause discolouration in foods.

TEMPERATURE

Different foods have their own optimum temperature for storage, which will prolong their shelf life. Usually warm temperatures are avoided during storage, as this can speed up the rate of enzyme activity, while freezing temperatures can cause some foods to break, like the protective shell surrounding eggs. Microorganisms usually thrive at room temperature, making fridge or freezer storage the best option for fresh foods. Between 10 and 37 degrees Celsius is the most common range in which food is handled. Just a ten degree increase in temperature can double the rate of chemical reactions within a food item.

© Getty

PHYSICAL DAMAGE

When bringing shopping into the house, you might take extra care with the softer fruits and food unprotected by packaging. Some fruits and vegetables have their own protective layer, but when this is damaged, threats such as microorganisms, air and small creatures can get into the food, increasing the rate of spoilage.

© Getty

MEET THE MICROBES

HOW DO THESE CELLS FORM COLONIES, CONTAMINATING OUR FOOD?

Mould

Foods that contain moisture are prime targets for mould. Growing from spores, which are carried in the air around us, these thread-like fungal structures can become harmful when they are ingested. Coming into contact with food, they use the food's nutrients to multiply, spreading over the surface and throughout the food. When enough mould has accumulated, it can usually be observed in furry or dusty-looking patches of white, or shades of green.

Mould's ability to withstand high concentrations of sugar and salt means that it can thrive on foods that bacteria and yeast can't. This is why it is commonly found living in jams, which bacteria struggle to survive in, and often feeds on the sugar in bread, fruit and vegetables. Foods with a high water content are also prime targets, but processed foods can usually fight off mould due to the high levels of preservatives added to them.

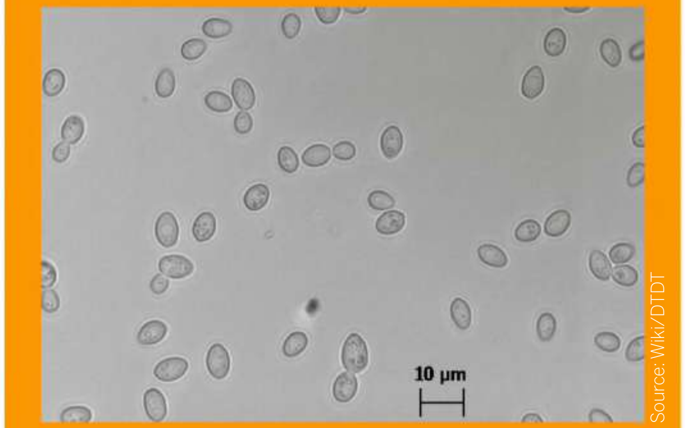
© Getty

The grey mould found on strawberries is caused by the fungus *Botrytis cinerea*

Out-of-control yeast

These single-celled fungi are often purposefully added to food. Feeding on sugars, the cells release carbon dioxide, which is beneficial for the baking of dough, as it makes it rise. Although a little yeast in food is good for you, when uncontrolled growths of yeast enter the body, it can cause infection.

Different strains of yeast can tolerate different acidities in food, but yeasts are typically the most prevalent microbe for spoiling carbonated products such as fizzy drinks. This is due to their ability to survive in environments of very low pH and high carbonation. By producing ethanol as a waste product, spoilage yeasts can drastically change the taste of drinks it contaminates. It can also eat away at preservatives, which further reduces the shelf life of food and drink.

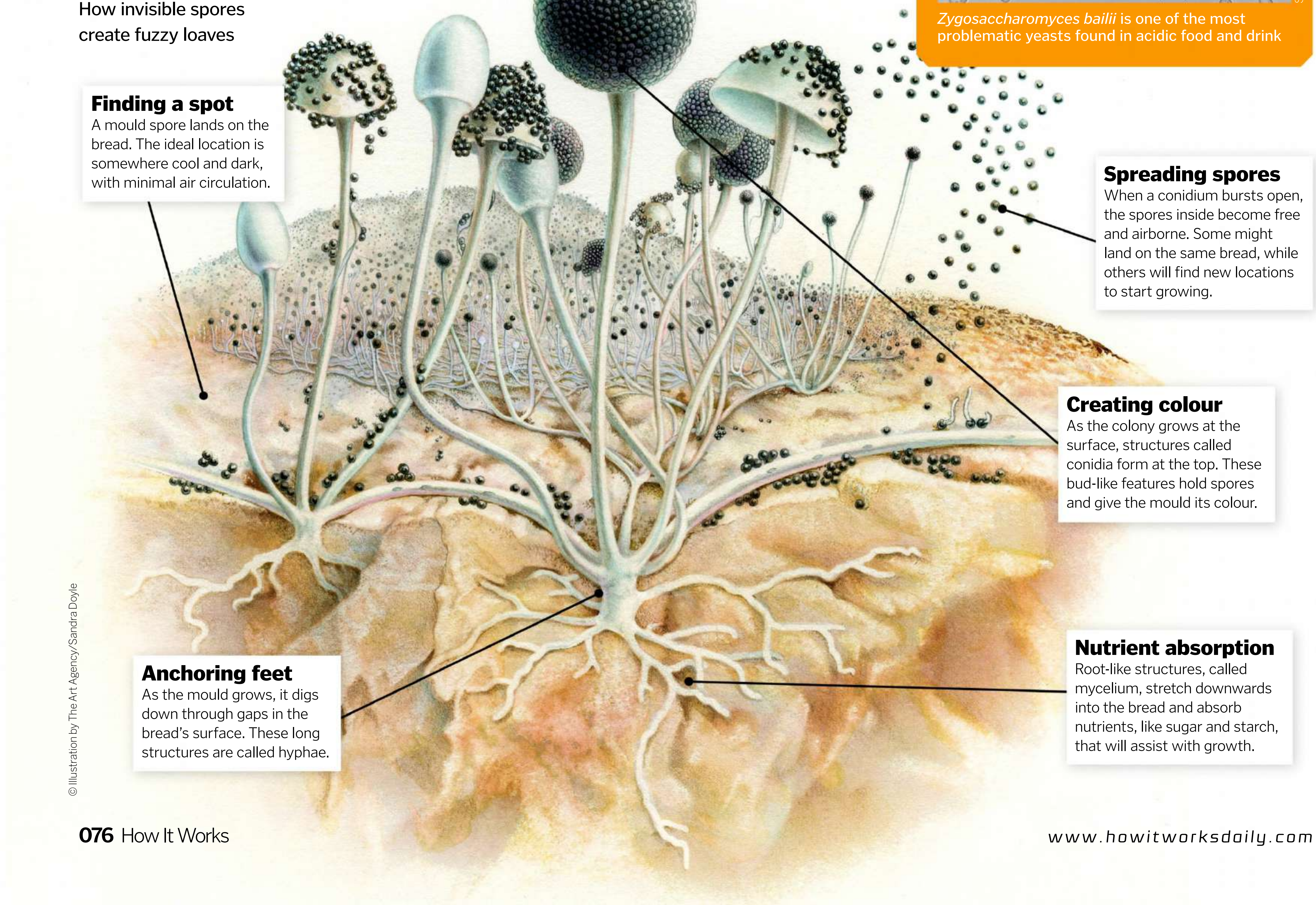


Source: Wiki/DTDT

Zygosaccharomyces bailii is one of the most problematic yeasts found in acidic food and drink

The spread in bread

How invisible spores create fuzzy loaves



Finding a spot
A mould spore lands on the bread. The ideal location is somewhere cool and dark, with minimal air circulation.

Spreading spores
When a conidium bursts open, the spores inside become free and airborne. Some might land on the same bread, while others will find new locations to start growing.

Creating colour
As the colony grows at the surface, structures called conidia form at the top. These bud-like features hold spores and give the mould its colour.

Nutrient absorption
Root-like structures, called mycelium, stretch downwards into the bread and absorb nutrients, like sugar and starch, that will assist with growth.

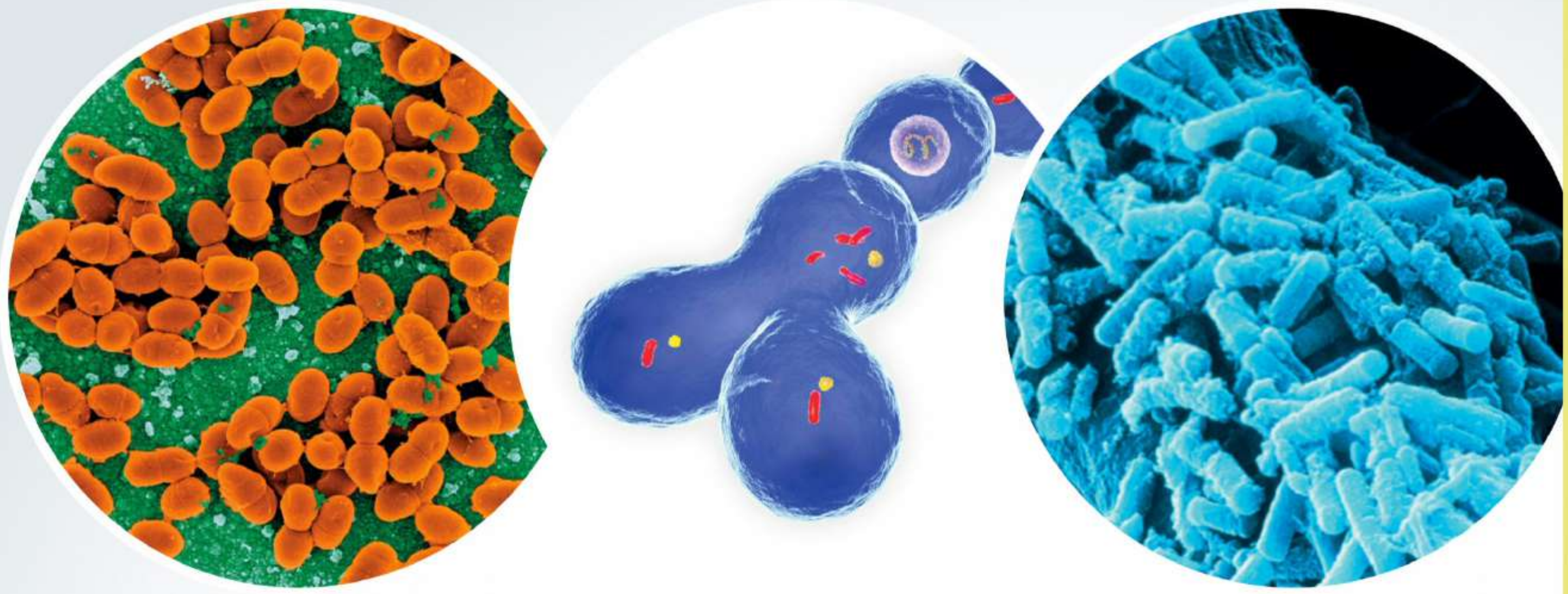
Anchoring feet
As the mould grows, it digs down through gaps in the bread's surface. These long structures are called hyphae.

© Illustration by The Art Agency/Sandra Doyle

DID YOU KNOW? *A one degree Celsius difference in fridge temperature can translate to a one-day difference in shelf life*

HEAT-RESISTANT BACTERIA

THESE THREE BACTERIAL GROUPS CAN LIVE ON FOOD IN A RANGE OF TEMPERATURES



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Psychrotrophs

LACTOCOCCUS PISCIUM

Psychrotrophic bacteria are those that can grow in low temperatures. Some species have been known to survive at zero degrees Celsius or lower, but most have an optimum growing temperature between 10 and 20 degrees Celsius.

Multiplying at low temperatures is a cause for concern when it comes to food, as the cooler climate of the refrigerator will not work in preventing these microbes from growing. *L. piscium* is one of the most common of all food-spoiling bacteria found in fridge-stored products. It mainly targets meat, giving it a sour smell.

Mesophiles

LEUCONOSTOC CITREUM

These bacteria thrive in much more moderate temperatures, between 25 and 35 degrees Celsius. Keeping food products in the fridge is a great way to keep them fresher for longer, preventing these bacteria from growing. Meat often has naturally occurring bacteria, and so keeping it cool before cooking stops this bacteria multiplying.

L. citreum is a specific mesophile, called a lactic bacterium. This means that it can live without needing any oxygen, and is a threat to food items like cooked ham, which is kept in vacuum-packed packaging for freshness.

Thermophiles

GEOBACILLUS STEAROTHERMOPHILUS

Heating food over a flame is a key way to kill lurking microbes, but not all microbes are heat-haters. Thermophilic bacteria actually benefit from this heat, living in temperatures above 45 degrees Celsius. *G. stearothermophilus* is one thermophilic species, causing problems largely within the dairy industry. Being immune to the heat treatment of milk, it causes much of the spoilage in non-refrigerated dairy products. The bacteria doesn't hold significant health risks, but causes unwanted fermentation and souring in many heat-treated food products.

Best before vs use by

Spoiled foods are not always visibly apparent, and so many of us rely on the expiry dates that have been printed on their packets. But why do some packets say 'best before', while others give a 'use by' date? It's important to know the difference between these two, because while one is there to prevent you from encountering an unpleasant taste, the other is printed for your health.

Food that has passed its best-before date can still be safe to consume, but isn't in its peak condition. Use-by dates are chosen for food that goes off quickly, such as meats and fish. You can eat the food up until the date printed, but when this date passes, you should throw it away. You shouldn't eat food or drink with an expired use-by date, even if it looks and smells normal, as it could make you ill.

4.05
Sirloin Steak

© Getty

About 30 per cent of the 'expired' food we throw away had a 'best before' date and could still been eaten

SIX TRICKS TO STOP FOOD GOING BAD

1 **Berry bath**
Wash your berries in a diluted vinegar bath before rinsing, drying them on paper towels and storing in the fridge. This can kill any lingering bacteria and mould spores and extend their shelf life.

2 **Crisp celery wrap**
Keeping celery in its loose plastic bag can cause it to go limp. This is due to the release of the ripening hormone ethylene. Over time this gets trapped in the bag, building up to become over-ripe. Wrap celery in foil instead, which allows the hormone to be released.

3 **Tomatoes out the fridge**
Tomatoes that are kept in the fridge can lose their flavour and become slightly too soft in texture. For the freshest, most flavoursome tomatoes, keep them in the cupboard.

4 **Onion and potato enemies**
You should store your potatoes away from onions if you want to keep them for a while. Next to each other, the ethylene gas released by onions will cause potatoes to sprout prematurely.

5 **Plastic-free mushrooms**
When mushrooms go bad, the water they release encourages bacterial and fungal growth, producing a slimy covering on their surface. If you remove the container they're sold in and wrap them in paper, this can absorb some of the excess moisture.

6 **Separate bananas**
Being connected in a bunch makes bananas ripen at the same time. As you are unlikely to eat the whole bunch at the same time, separating them helps to avoid them all going brown together.

6x © Getty

How we hear

See inside the vital organs that help us to communicate and make sense of our surroundings

Words by **Ailsa Harvey**

Our ears are always alert. Whether we are relying on them to relay the sounds of verbal conversations or placing devices into them to listen to music, these organs have the power to enhance our lives.

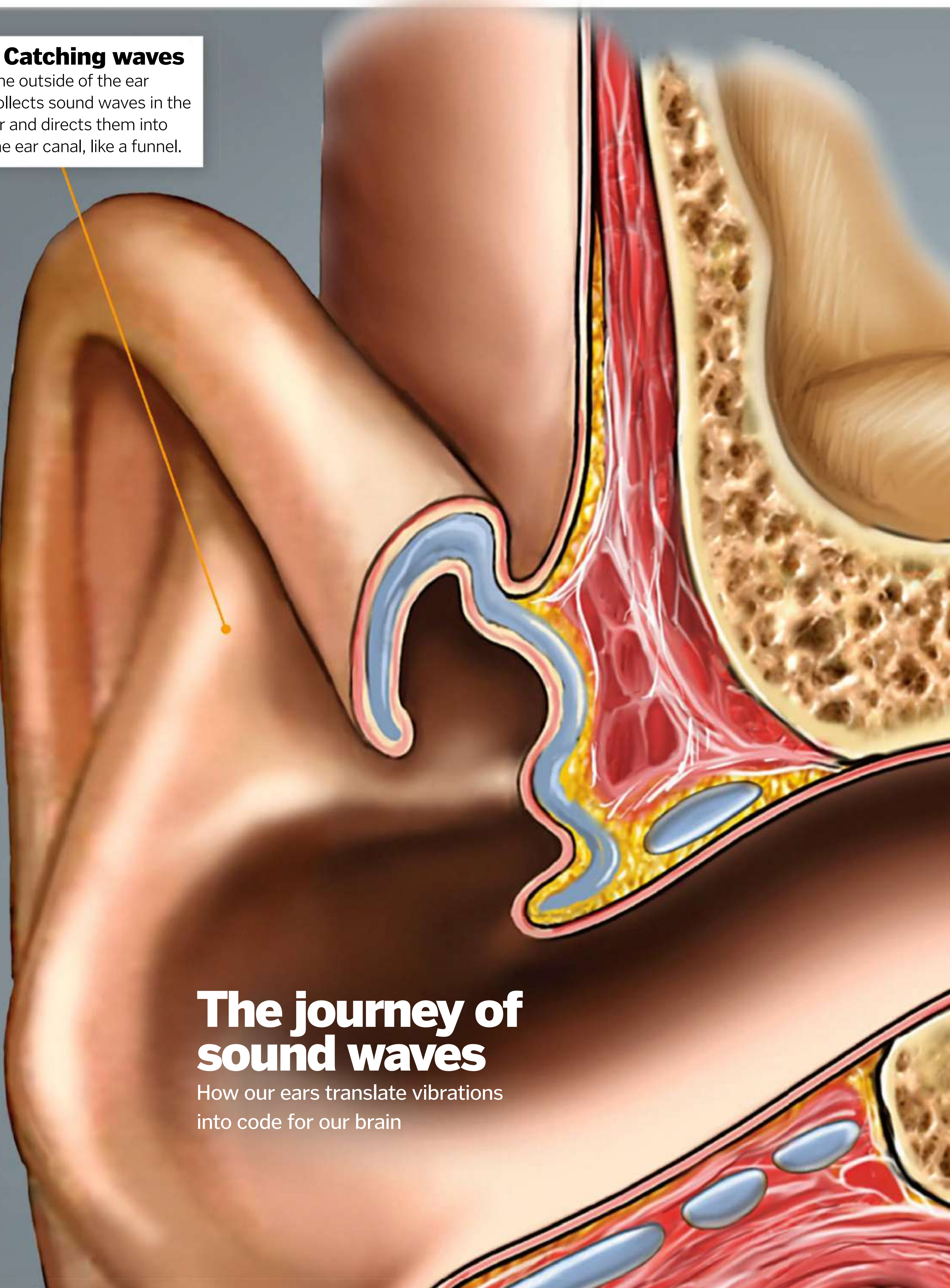
Hearing not only brings us joy through the pleasant sounds of our favourite melodies and the calming noises of nature, it also serves as a life-saving function. When danger approaches, our ears can act as first responders, detecting the sound of footsteps behind us, speeding cars or the warning of a fire alarm. The ability to hear these sounds means we can sense things from more than one direction at a time – something our eyes alone cannot achieve.

As the human body has evolved, we have become more responsive to sounds that might indicate danger. Sounds of a higher frequency are amplified in our ears, making us more likely to react. This is also the reason so many of us dislike certain noises, such as nails scratching a chalkboard. Research shows that this sound is in the same frequency range as a human scream or a crying baby. An urgent response to these noises has proven beneficial to our species when attending to someone in danger.

People are born with different levels of hearing. However, our increased knowledge of how our ears function has allowed us to create technology that improves some people's ability to hear. Hearing aids are equipped with microphones that, when attached to ears, can amplify the sound that reaches them. For more severe hearing loss, cochlear implants can be embedded inside the ear. This implant takes on the work of the cochlear by converting any sound detected into electrical impulses for the brain to process.

The journey of sound waves

How our ears translate vibrations into code for our brain



1 Catching waves
The outside of the ear collects sound waves in the air and directs them into the ear canal, like a funnel.

Young children are more sensitive to loud noises because their ear canals are smaller

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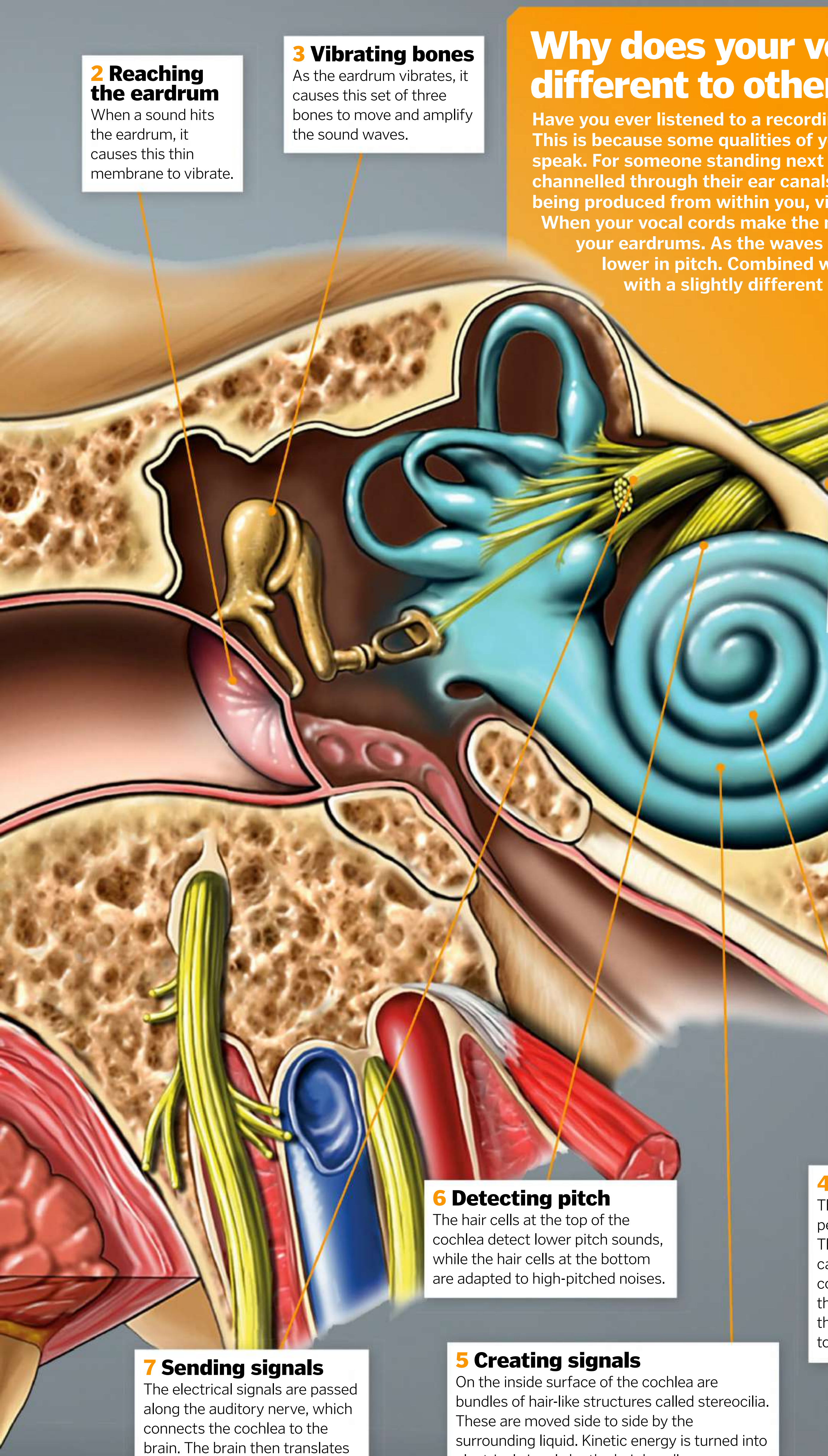

2 Reaching the eardrum

When a sound hits the eardrum, it causes this thin membrane to vibrate.

3 Vibrating bones

As the eardrum vibrates, it causes this set of three bones to move and amplify the sound waves.

4 Cochlea receival

The cochlea is the size of a pea, and is filled with fluid. The third of the three bones, called the stapes, is in contact with the cochlea. As this bone moves, it causes the liquid inside the cochlea to form rippling waves.

5 Creating signals

On the inside surface of the cochlea are bundles of hair-like structures called stereocilia. These are moved side to side by the surrounding liquid. Kinetic energy is turned into electrical signals by the hair bundles.

6 Detecting pitch

The hair cells at the top of the cochlea detect lower pitch sounds, while the hair cells at the bottom are adapted to high-pitched noises.

7 Sending signals

The electrical signals are passed along the auditory nerve, which connects the cochlea to the brain. The brain then translates these signals into sounds we can understand.

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Why does your voice sound different to other people?

Have you ever listened to a recording of your voice and thought it didn't sound like you? This is because some qualities of your voice sound different to those around you as you speak. For someone standing next to you, the sound of your voice will be detected as it is channelled through their ear canals. The same will happen in your ears, but as the speech is being produced from within you, vibrations will also reach your eardrums via another route. When your vocal cords make the noise, the vibrations travel up through your skull to reach your eardrums. As the waves move through bone, they stretch out more to become lower in pitch. Combined with the external sound waves, the outcome is a voice with a slightly different tone to what others hear.

Some people don't like listening to recordings of their voice, as it sounds different to what they're used to hearing

© Getty

5 FACTS ABOUT CAUSES OF HEARING LOSS

1 Sound exposure
Prolonged exposure to loud noises can damage the tiny hairs inside your ears that communicate with the brain.

2 Ageing
As you get older, it can become more difficult to pick out high-pitched noises from background noise. This is due to gradual wear and tear to the ears' hairs and nerve cells.

3 Blockage
Sometimes hearing can be significantly reduced by blockages in the ear canal. Substances such as ear wax can block the route for sound waves.

4 Infection
Ear infections near the eardrum can cause a buildup of fluid next to it. This limits the ability of the eardrum to vibrate, hence limiting the sounds recorded.

5 Ruptured drum
Extreme changes in air pressure or sudden loud noises can create a hole in your eardrums. This not only causes pain, but impacts their function.

> *"Sounds of a higher frequency are amplified in our ears"*

How your metabolism works

Discover the many ways our bodies stay energised

Words by **Scott Dutfield**

We often mistake our metabolism as something that happens in a certain part of the body, such as in the digestive system, and something you can boast about at the gym. However, this isn't the case. Metabolism occurs within every one of the 37.2 trillion cells that make up each human body and describes a myriad of different biochemical reactions, not just how fast you burn fat.

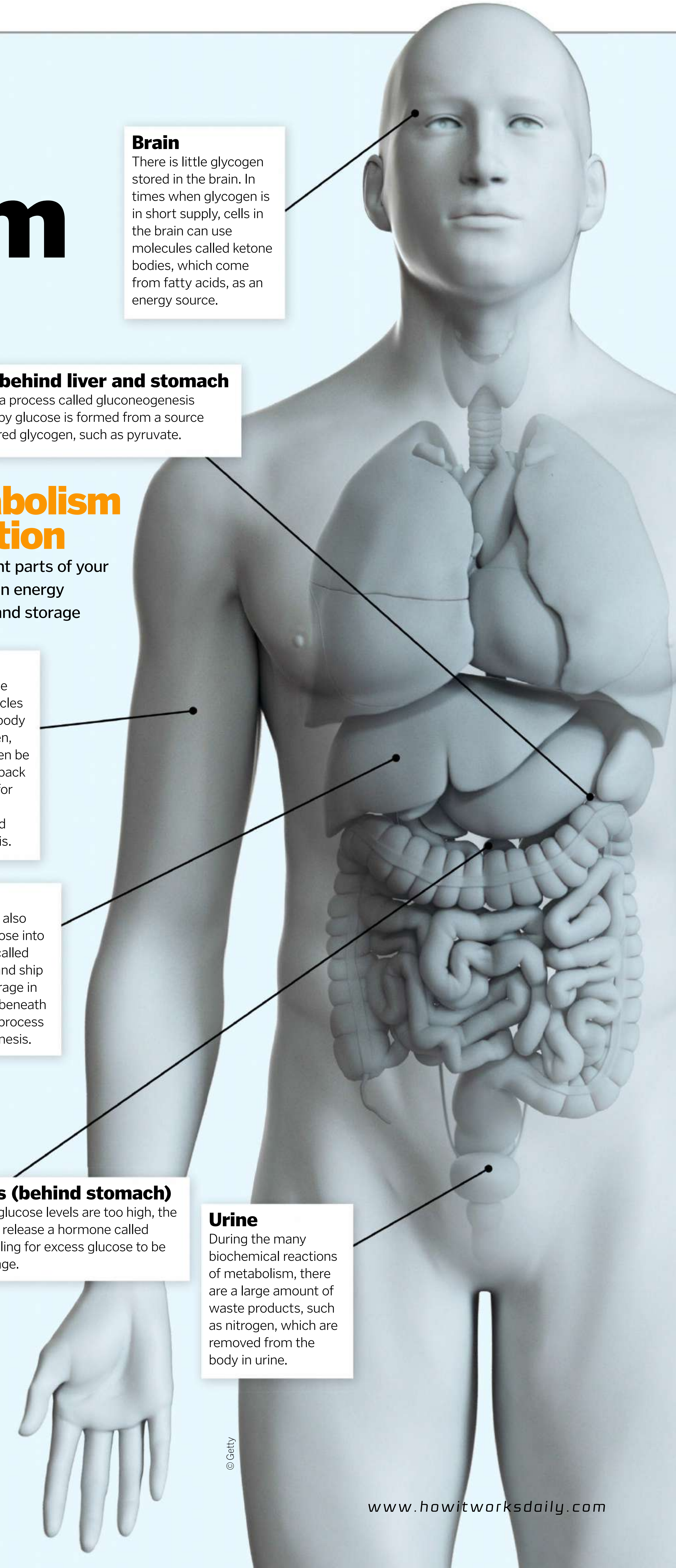
Your metabolism is the combination of two types of biochemical reaction. Catabolic reactions break down the molecular nutrients, such as carbohydrates, vitamins and fats, from the foods we eat for energy release, whereas anabolic reactions assemble different molecules for energy storage. These two types of reaction work in tandem to maintain a biological harmony in the human body called homeostasis.

While the nutrient molecules of water, minerals, proteins, fats and vitamins are vital for our survival in other ways, such as physically building our bodies, the release of energy comes from the metabolism of carbohydrates. On a cellular level, glucose molecules, found in carbohydrates, are broken down to release energy in the form of a compound called adenosine triphosphate (ATP). ATP is essentially the driving force of your body's metabolism, converting energy from digested glucose or using up glucose that has been stored in the body as long-chain molecules called glycogen.

However, not everyone's metabolism is the same. Genetics mostly determines the rate of metabolism, irrespective of a body's size. There are many factors that can either speed your metabolism up or slow it down, such as age and gender. To function normally, the amount of energy needed, referred to as the basal metabolic rate (BMR), is around 7,100 kilojoules (kJ) per day for the average man and 5,900 kJ per day for the average woman. When we provide our bodies with more nutrients than we need to fulfil this energy demand, we store it as fat, and when we don't supply our body with enough energy our metabolism uses the stored fat.

Metabolism in action

How different parts of your body assist in energy production and storage



Brain
There is little glycogen stored in the brain. In times when glycogen is in short supply, cells in the brain can use molecules called ketone bodies, which come from fatty acids, as an energy source.

Kidneys (behind liver and stomach
In the kidneys a process called gluconeogenesis occurs, whereby glucose is formed from a source other than stored glycogen, such as pyruvate.

Muscle
Along with the liver, the muscles around your body store glycogen, which can then be metabolised back into glucose for energy in a process called glycogenolysis.

Liver
The liver can also convert glucose into a fatty acid called triglyceride and ship it out for storage in the fat layer beneath the skin in a process called lipogenesis.

Pancreas (behind stomach)
When blood glucose levels are too high, the pancreas will release a hormone called insulin, signalling for excess glucose to be put into storage.

Urine
During the many biochemical reactions of metabolism, there are a large amount of waste products, such as nitrogen, which are removed from the body in urine.

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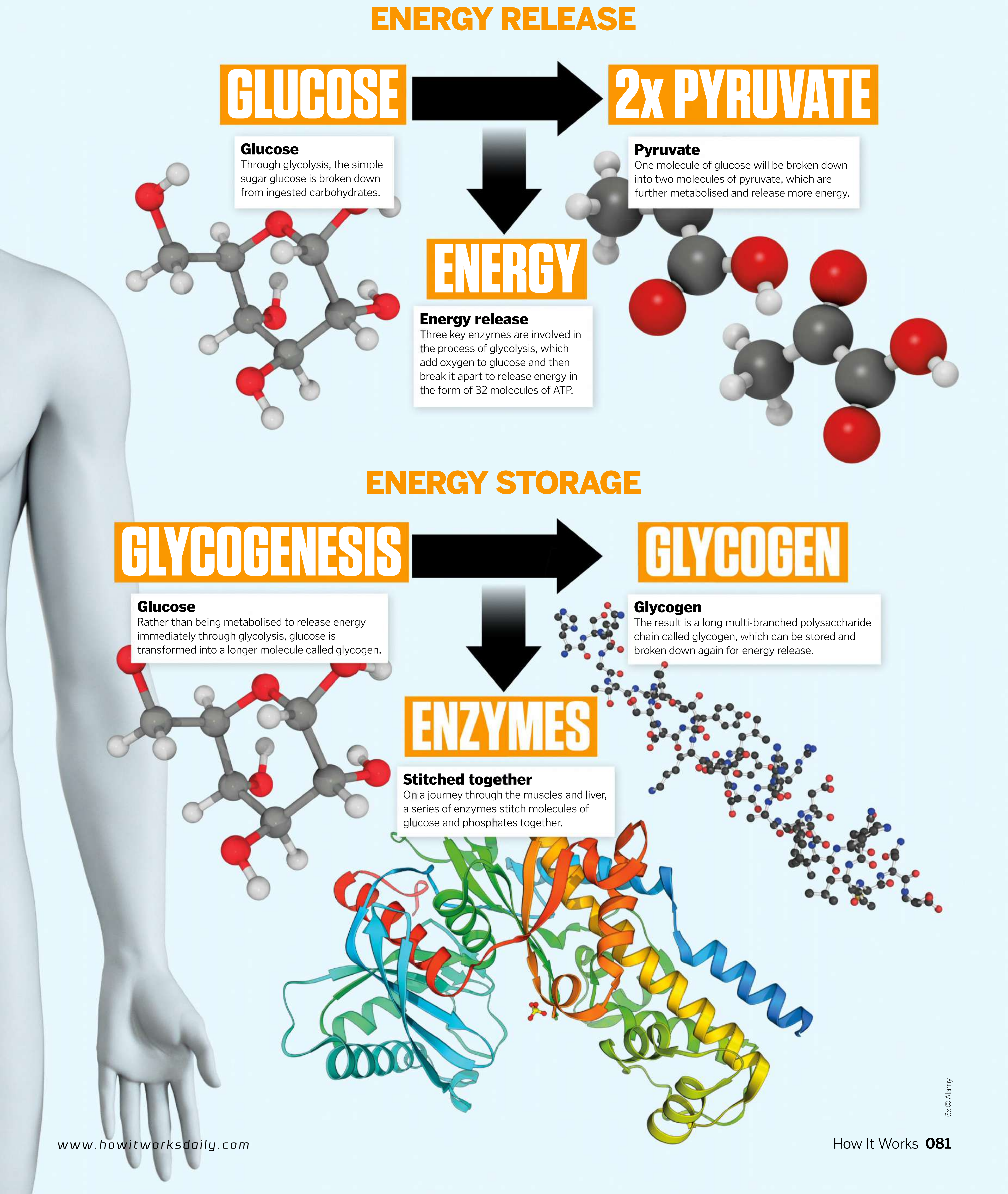

ENERGY RELEASE

GLUCOSE → 2x PYRUVATE

↓ ENERGY

Glucose
Through glycolysis, the simple sugar glucose is broken down from ingested carbohydrates.

Pyruvate
One molecule of glucose will be broken down into two molecules of pyruvate, which are further metabolised and release more energy.

Energy release
Three key enzymes are involved in the process of glycolysis, which add oxygen to glucose and then break it apart to release energy in the form of 32 molecules of ATP.

ENERGY STORAGE

GLYCOGENESIS → GLYCOGEN

↓ ENZYMES

Glucose
Rather than being metabolised to release energy immediately through glycolysis, glucose is transformed into a longer molecule called glycogen.

Glycogen
The result is a long multi-branched polysaccharide chain called glycogen, which can be stored and broken down again for energy release.

Stitched together
On a journey through the muscles and liver, a series of enzymes stitch molecules of glucose and phosphates together.

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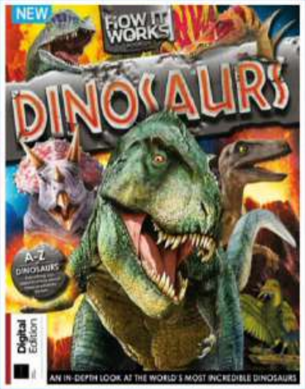
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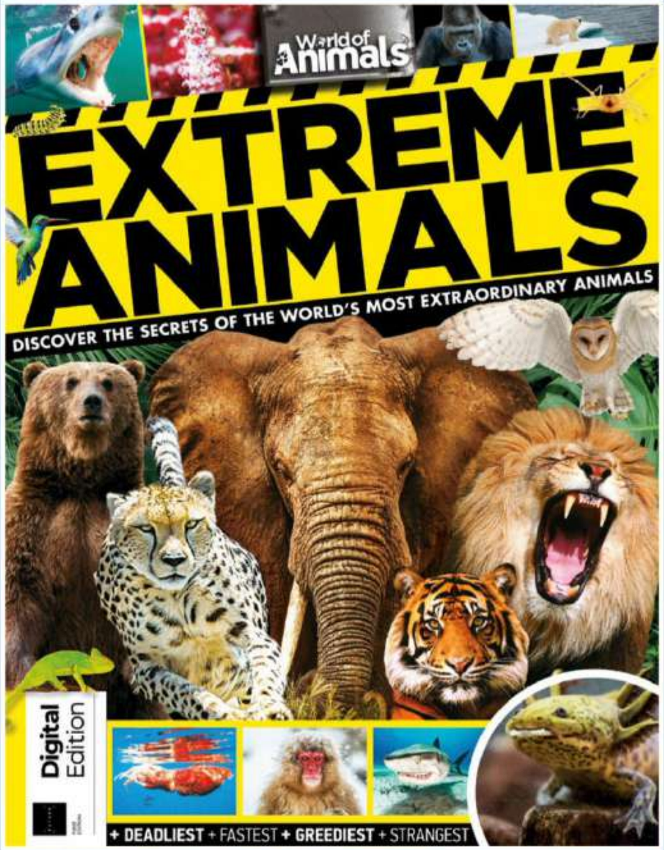
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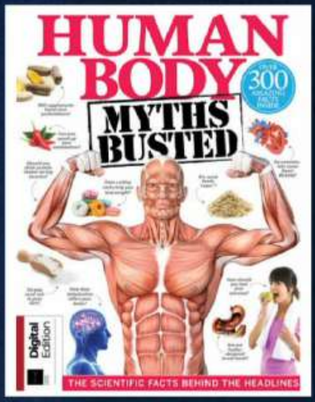
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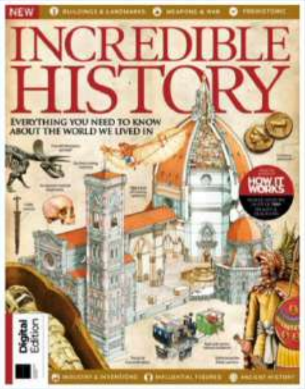
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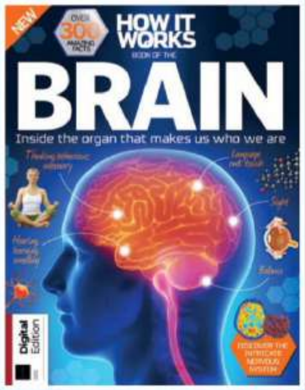
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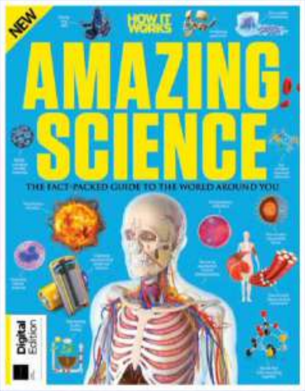
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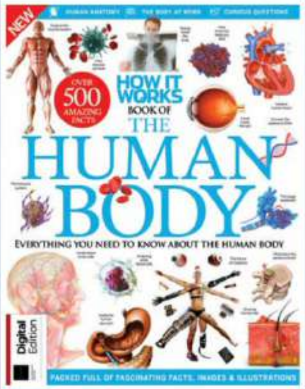
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BRAIN DUMP

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Red blood cells only live for 120 days. When it's time to die they are eaten by white blood cells

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SCIENCE

How do cells get their functions? Is there a particular time for cells to operate?

Jimmy Liu

■ A cell is an organism with its own biological clock. They regulate themselves and undergo division and regeneration automatically. They move, breed and grow independently and respond to changes in their environment. They generate their own energy and store it away to use later. The bulk of the cells in the human body look alike and have the same abilities. Other cells specialise in certain functions, and that determines what they look like and what they do. Nerve cells are designed to transmit messages around the nervous system, muscle cells grow in bundles so they can contract and reproductive cells combine to create new life. **AG**

WANT ANSWERS? Send your questions to...

How It Works magazine @HowItWorksmag @howitworks@futurenet.com

Scientists found evidence of emotions in sea bream in 2017. They think the trait evolved 375 million years ago

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ENVIRONMENT

Is it only mammals that have emotions?

Fran Baker

Humans can have difficulty understanding their own emotions at times. It's much harder to study what's going on in an animal's brain, especially as you can't talk to them. Scientists agree that a number of intelligent mammals have feelings, but they're not alone. Owners and keepers of birds, fish and reptiles report their animals showing love, joy and excitement. Behaviourists have demonstrated that lizards make decisions based on pleasure and that chickens are as emotionally complex as mammals. **AG**

DID YOU KNOW?

Robert Walpole is considered the first prime minister of the UK

The queen and prime minister work together, neither party holding all the power over the country

© Getty

HISTORY

Why does Britain have a queen and a prime minister?

Louise Prentiss

The power of the English monarchy was originally absolute. However, in 1215, King John signed the Magna Carta, acknowledging that the monarch's powers did have limitations. Taxes could no longer be raised without the consent of a council of feudal lords and religious officials, which eventually became the parliament we now recognise. Today the prime minister and the queen share power with a government, meaning that no one person has too much control over the people. **JE**

© Getty

ENVIRONMENT

Why are some plants' leaves purple?

scimaxfacts (Instagram)

A plant might have purple leaves for any one of a number of reasons, but it's usually because they've got a different colour pigment in their cells. The leaves might be rich in anthocyanin, a pigment that absorbs green and yellow light, making them appear reddish or purple. This protects new leaves from Sun damage and is also thought to protect tropical plants that grow in the shade of tall trees from fungal infections. When a plant that normally has green leaves – like marigolds and tomato plants – turns purple, however, it's usually because of a phosphorus deficiency. **BB**

BRAIN DUMP

SCIENCE

Why is poo brown when we eat food of various other colours too?

Jasleen Villa

■ Our poo is brown because we're constantly replacing our blood, with each blood cell lasting four months. As we break down old blood in our spleens, the chemical responsible for its red colour – haemoglobin – gets chopped up. One of the leftover parts is the yellow-brown compound bilirubin. This flows into our intestines in bile, where bacteria change it to the brown-coloured molecule stercobilin. However, you can often still see food colours in your poo! **AE**

Poo is brown because it contains waste products from blood, broken down in our spleen

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DID YOU KNOW?

The first space tourist, Dennis Tito, paid $20 million to fly to the ISS in 2001

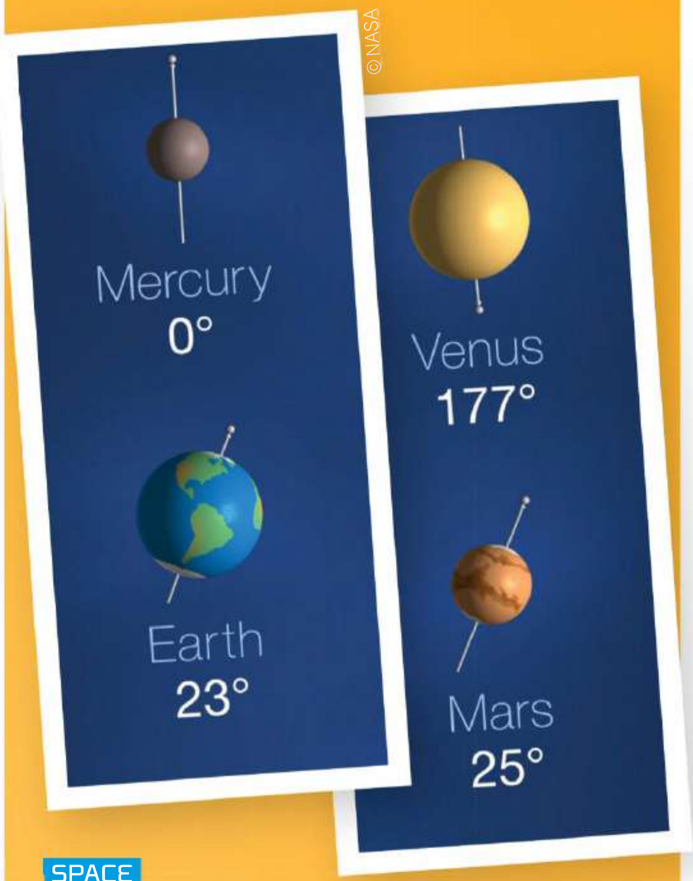
© Alamy

SCIENCE

Why is it that sometimes if I try to remember something I can't recall it, then it just comes to me later without trying?

Jonathan Nathaniel

■ Sometimes remembering something can be blocked by similar memories. Other times there's interference from newer memories. This happens more when a person is stressed. The answer usually pops into our heads later, after our internal computer has frozen. Once the 'bug' has been fixed the brain carries on looking for the memory. **AG**



© NASA

SPACE

Why doesn't Mercury orbit on a wonky axis?

Emlyn Morris

■ All the planets in the Solar System have a tilted spin axis relative to their orbit around the Sun, but in Mercury's case the tilt is tiny – less than a 30th of a degree. Another peculiarity is that due to Mercury's proximity to the Sun, strong tidal forces over billions of years have locked it into a 3:2 spin-orbit resonance. It's possible that similar tidal effects are responsible for the reduced axial tilt. **AM**

GREAT SCOT
YARD SW1
CITY OF WESTMINSTER

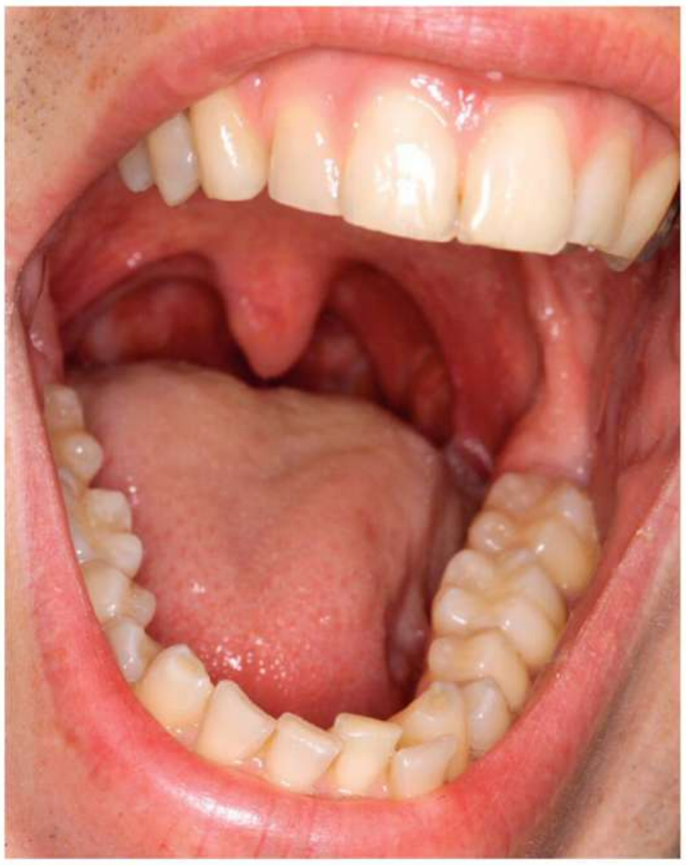
© Getty

HISTORY

Why is it called 'Scotland Yard' when it's in London?

Jennifer Whitlow

■ The Metropolitan Police headquarters used a back entrance leading into an area known as Great Scotland Yard, which was once the site of a medieval palace owned by Scottish royalty. **JE**



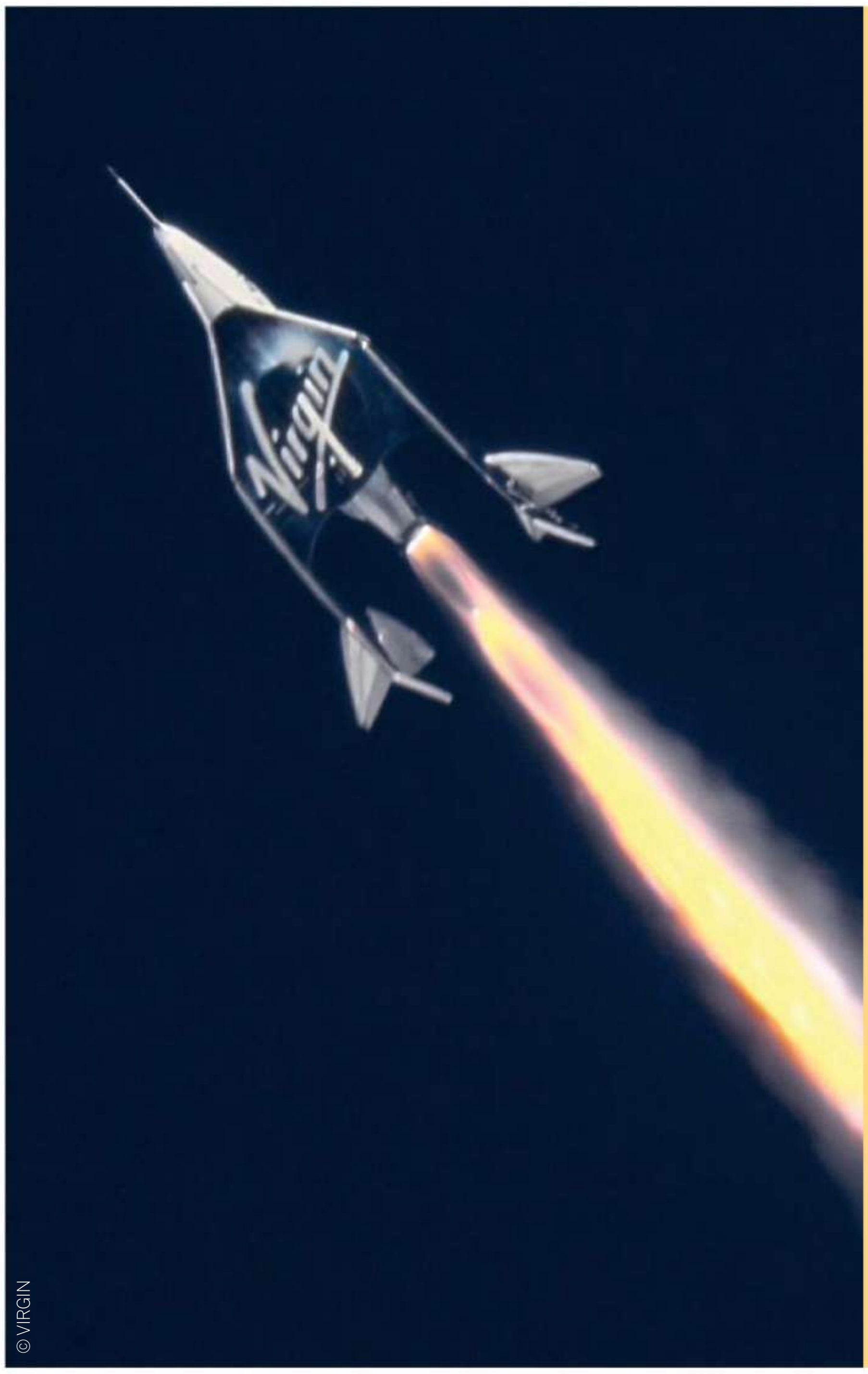
© Getty

SCIENCE

Are we constantly producing saliva?

Donna Whittington

■ Yes. We normally produce the equivalent of about two ketchup sachets per hour. We produce around a quarter of this when asleep, and ten times as much when we're eating. **AE**



© VIRGIN

Virgin Galactic's VSS Unity took three people into space on a test flight

SPACE

Will we ever be able to go on trips to space?

sammy.glanfield (Instagram)

■ There'll soon be many ways civilians, rather than astronauts, can take a trip into space. Six different companies plan to offer flights into space within the next few years, including Richard Branson's Virgin Galactic, Elon Musk's SpaceX and Jeff Bezos' Blue Origin. One flight by Axiom Space is scheduled to take passengers to the International Space Station (ISS) in January 2022. However, unless you've got a spare $55 million (£40 million) lying about for a ticket, you'll have to wait a while before a voyage beyond the Kármán line becomes affordable. **BB**

ENVIRONMENT

How can some birds fly as high as aeroplanes?

Janet Stokes

■ Bar-headed geese have been clocked at 7,290 metres. It's harder to grab oxygen from the air at such high altitudes, so these birds have enormous lungs that supply oxygenated blood straight to the wing muscles. They can breathe seven-times faster than normal and have cells packed with energy-producing mitochondria. **AG**

© Alamy

DID YOU KNOW?

The smallest and largest human cells are male and female reproductive cells.

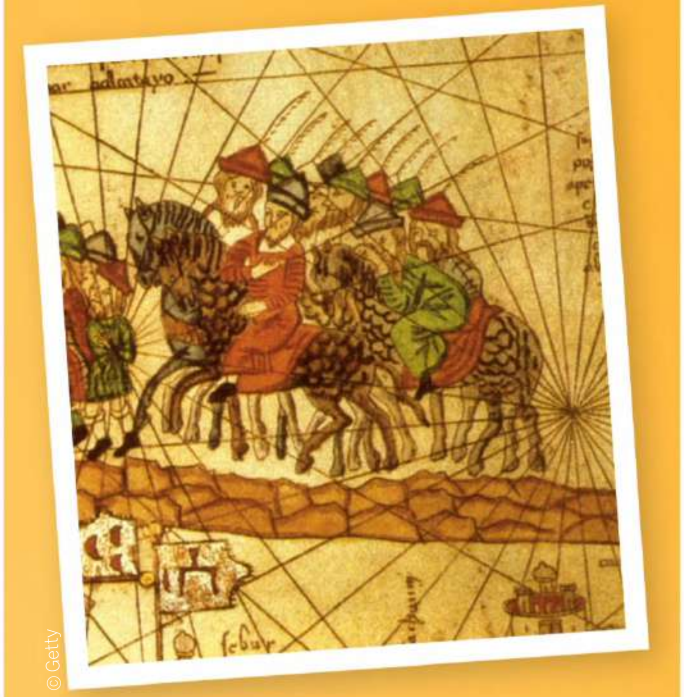
© NASA

SPACE

Do all galaxies rotate?

Salma Hakim

■ Galaxies don't rotate like solid objects; the stars in them move on various orbits to produce a whirlpool-like rotation that varies with radius. Elliptical galaxies generally rotate slower than spirals. **AM**



© Getty

HISTORY

Was the Silk Road a real road?

Andy Carr

■ The Silk Road was actually a number of roads that acted as trade routes, linking China with the West. Silk was taken across to the West, while wool, livestock and precious metals were carried eastward along 4,000 miles of track. Language, philosophy and religions were also shared in this way. **JE**

DID YOU KNOW?

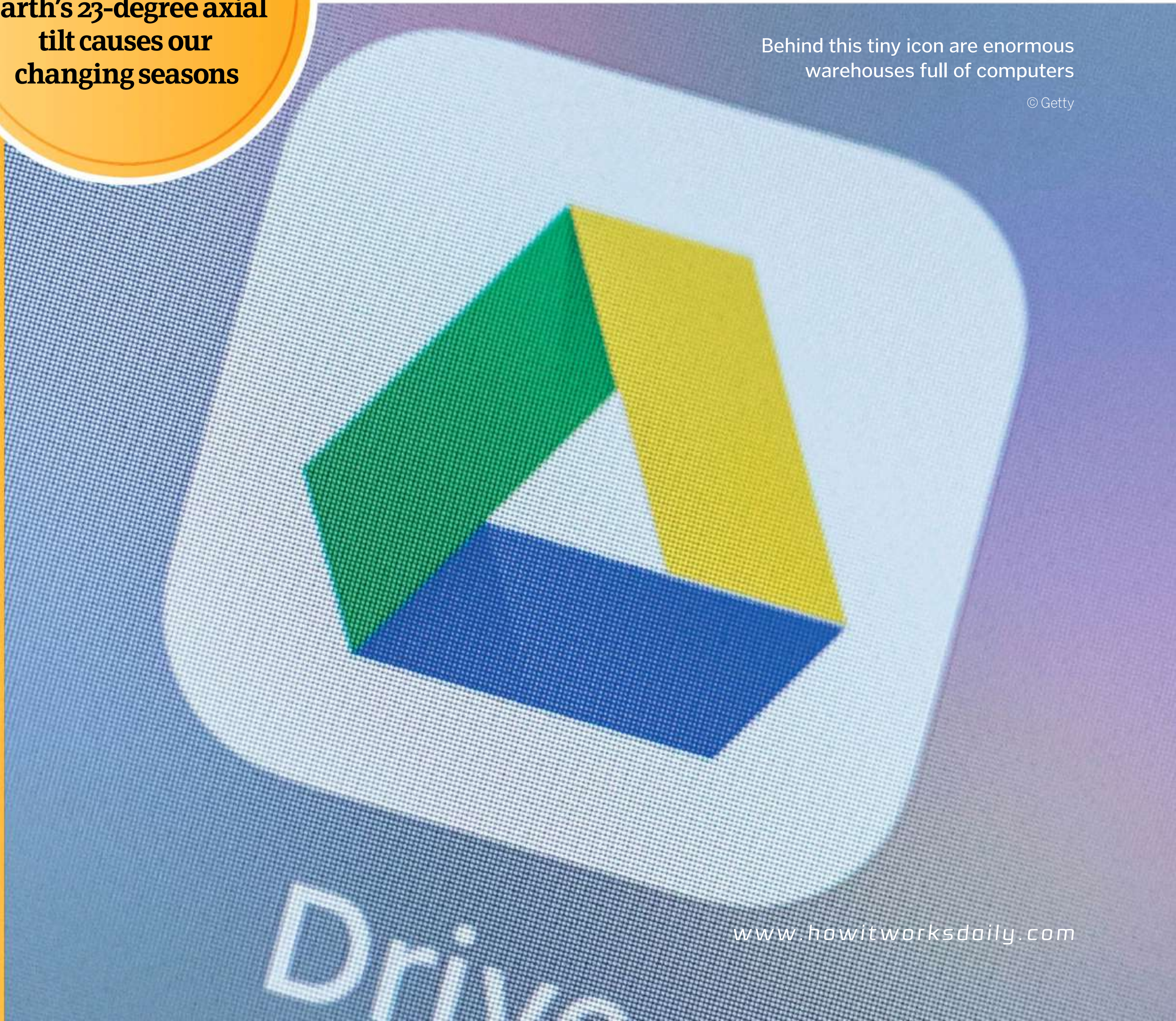
Earth's 23-degree axial tilt causes our changing seasons

TECHNOLOGY

How much Drive space does Google have? Could it run out?

Tia Gibbons

■ Google has 22 data centres around the world, each an enormous warehouse full of computers. In 2011, Randall Munroe, creator of the comic xkcd, estimated that Google had 10 billion terabytes of space on computers called servers, and another 5 billion terabytes stored on magnetic tape. One person's Google Drive account is 15 gigabytes. Each terabyte can therefore contain 266 people's Drive accounts. 15 billion terabytes can hold 3.99 billion Drive accounts. That's compared to 7.8 billion people alive today. Since 2011 Google's storage has grown further, and can do so until we run out of materials to make computers. **AE**



Behind this tiny icon are enormous warehouses full of computers

© Getty

18+

WHAT IS
AVAXHOME?

AVAXHOME -

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu

ENVIRONMENT

Why do trees live for so long?

James Hussman

■ Trees grow extremely slowly. While the average height of a one-year-old human is approximately 75 centimetres, a tree seedling will often only reach 15 centimetres, so it conserves its energy and takes its time. The stem cells of a tree, known as 'meristems', can choose to divide or not, depending on the surrounding environment. This means that the cells can go dormant until conditions become favourable again. A tree can also decide how many branches and roots will be needed to sustain itself. Trees are able to replace damaged or lost organs, so they can remain fitter and healthier for longer. **JE**

Trees conserve their energy by growing extremely slowly, taking hundreds of years to reach maturity

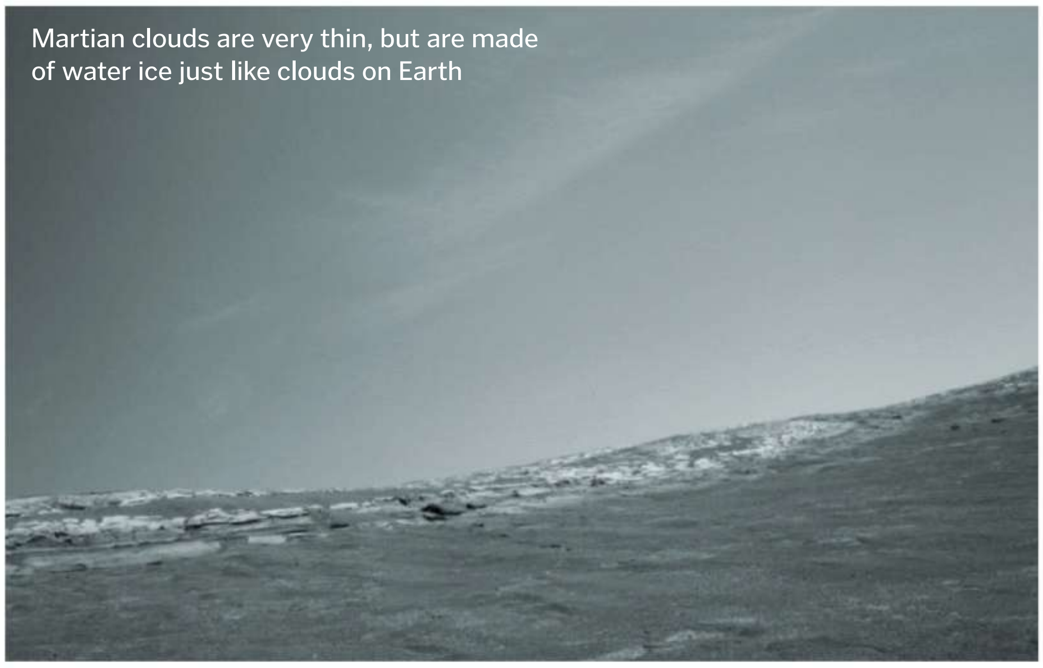
© Getty

SPACE

Are Venus and Earth the only cloudy planets?

Gina O'Neil

■ Clouds on Earth are formed from water droplets and ice crystals. The only other planet in the Solar System with primarily water-based clouds is Mars, although these are generally very thin and wispy, and don't often show up in photographs. But if we look beyond water, then any planet with an atmosphere can form clouds. The distinctive clouds enveloping Venus, for example, are composed mainly of sulphuric acid, while those on the gas giants – Jupiter and Saturn – are primarily ammonia. Yet another chemical, methane, is the main constituent of clouds on Uranus and Neptune, as well as Saturn's moon Titan. **AM**



Martian clouds are very thin, but are made of water ice just like clouds on Earth

© NASA

© Getty

TECHNOLOGY

How does bulletproof glass work?

Frank Finch

■ Bulletproof glass is usually made of one or more layers of toughened glass, combined with layers of slightly softer polycarbonate plastic material. Although a bullet still shatters the glass, the polycarbonate plastic slows the bullet down and usually stops it passing through, trapping it in a bulge. **AE**

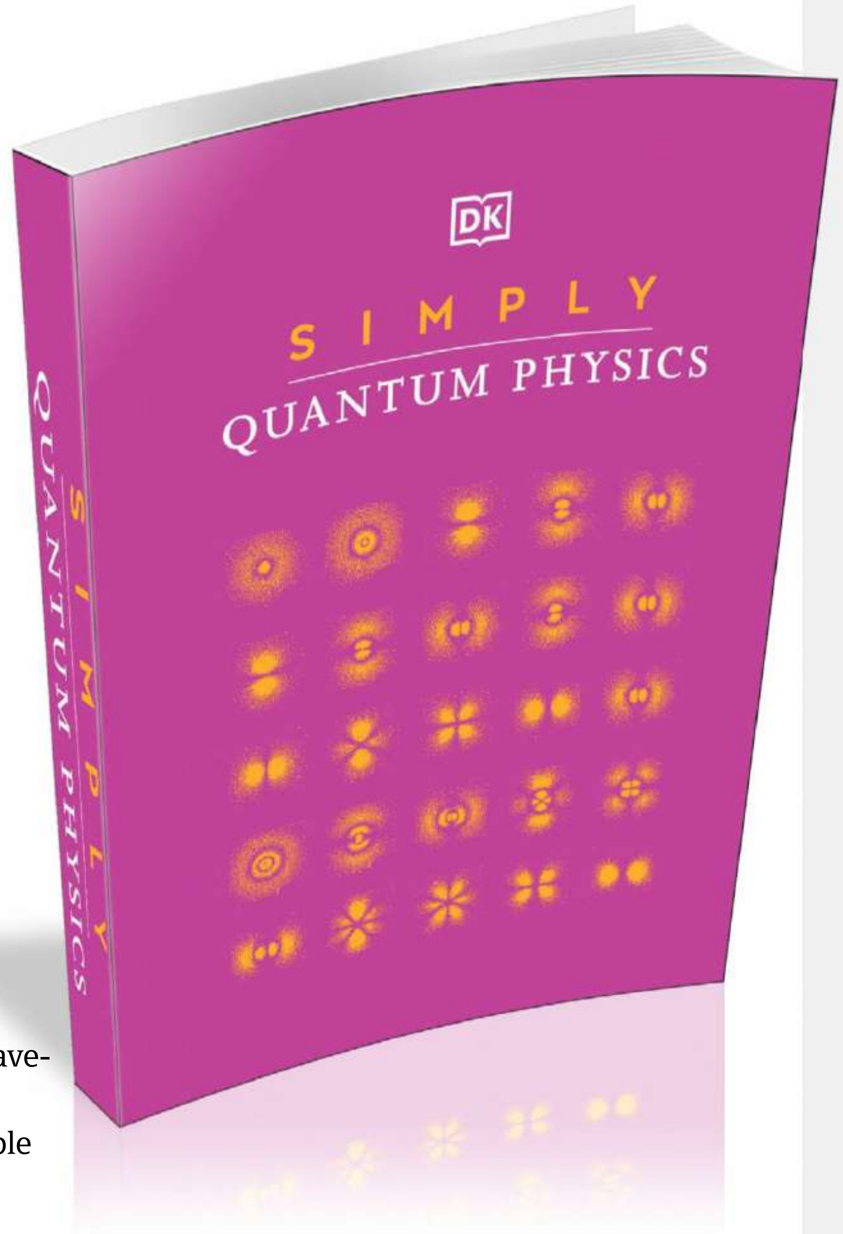
BOOK REVIEWS

The latest releases for curious minds

Simply Quantum Physics

IF YOU DON'T LOOK, IT DOESN'T EXIST

- Author: **DK**
- Publisher: **DK**
- Price: **£9.99 / $12.59**
- Release: **Out now**



Protons, neutrons, gluons, beta decay, wave-particle duality, Planck's constant, Schrödinger's cat – there's nothing simple about quantum physics whatsoever. We can't even see the particles (or waves?) it describes with our naked eye because things at a quantum level are billions of times narrower than the width of a human hair. Our most powerful light microscopes can't even get close to resolving an image of an atomic nuclei, so the only way we can observe something as small as that is with a device that fires other subatomic particles at it – an electron microscope. And we still don't really understand why Schrödinger's cat is both dead and alive, though it does make sense that it would climb into a deadly radioactive box… cats love boxes after all.

It sounds like the authors of *Simply Quantum Physics* have set themselves an incomprehensible task. But they've done a stellar job here, all the while resisting the temptation to fill the pages with hefty terminology and mind-bending thought experiments. It starts with a little bit of history and an eye-popping scale with a length so small we don't have enough space on the rest of this page to fit all the zeros in, then suddenly we're completely engaged.

There isn't much frame of reference to explain to people who aren't quantum physicists how this strange world works, so here the authors use history, physical laws that will be more familiar to the reader – Newton's law of motion, for example – and a slew of simple graphics. The familiar technologies that have emerged from quantum physics, including the electronics in sophisticated timekeeping devices and, of course, quantum computers, aren't dealt with until we're long past the basic principles. But when you've got weird and wonderful phenomena like quantum entanglement – where pairs of particles match each other's state no matter how far apart they are – and the theory of parallel universes to read about, satellites and microchips seem less exciting.

Unsurprisingly, we wouldn't recommend this book for primary school children, unless they're remarkably bright. But anyone interested in the crazy world of quantum physics from middle school-age upwards might enjoy giving *Simply Quantum Physics* a shot.

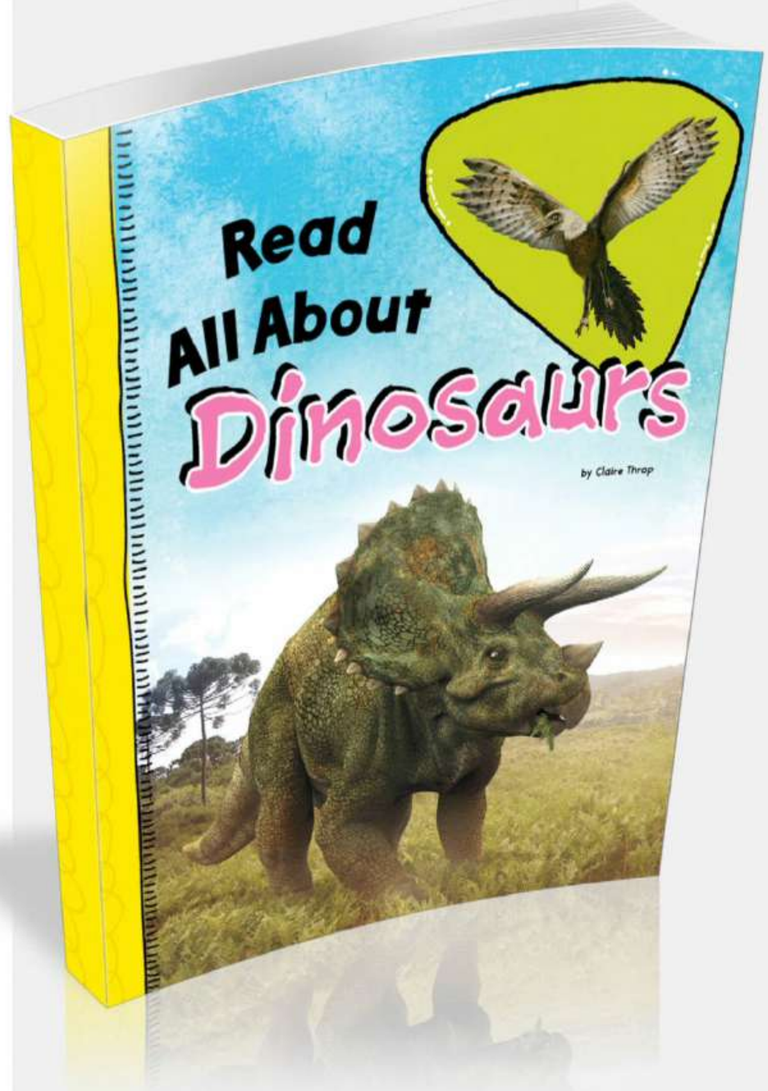
> We still don't really understand why Schrödinger's cat is both dead and alive

Read All About Dinosaurs

THE DINO ENCYCLOPEDIA FOR KIDS THAT'S FILLED WITH PREHISTORIC FACTS

- Author: **Claire Throp**
- Publisher: **Pebble Books**
- Price: **£21.14 (approx. $29)**
- Release: **1 August**

As the title suggests, this book gives children a whole host of facts about the diverse world of dinosaurs. Full of fun depictions of these ancient animals, this book is aimed at young children, who will likely be mesmerised by the creatures of the prehistoric world. Each illustration comes with its own fact. For example, you might be surprised to find out that a stegosaurus was around eight metres long, but its brain was the size of a walnut. This is one of many books in the 'Read All About' series, and is a great way to introduce children to the world of nonfiction.



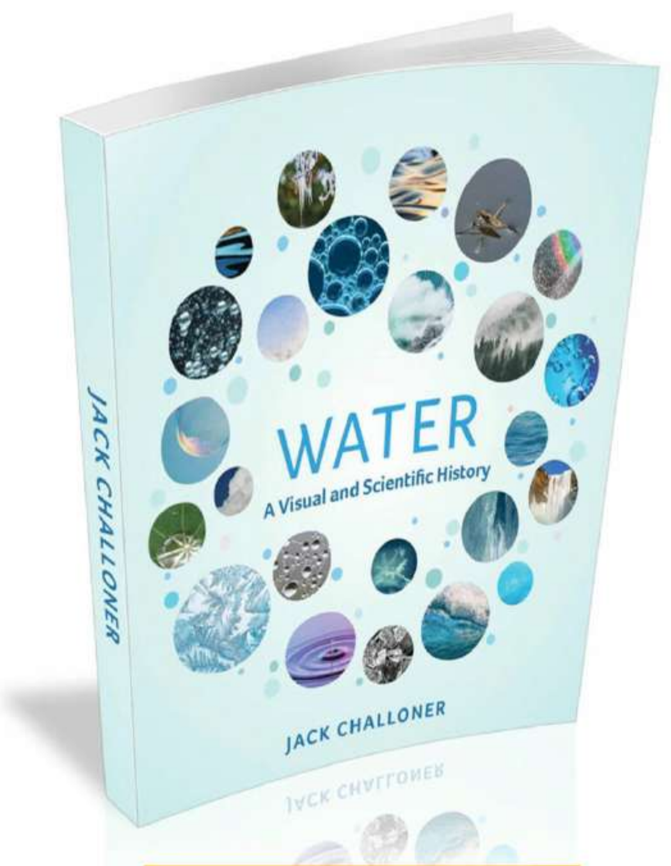
Water

A VISUAL AND SCIENTIFIC HISTORY

- Author: **Jack Challoner**
- Publisher: **MIT Press**
- Price: **£29.05 / $39.95**
- Release: **31 August**

Challoner leaves no stone unturned in this homage to water. From its cosmic origins to its cellular importance today, he explores this varied world. *Water* leans more on the side of a textbook, meaning that its content is very much rooted in offering scientific insight, rather than a popular science narrative. That being said, the way Challoner has structured the story of water flows nicely from its origins and the study of its chemical properties and abilities, to how this tiny molecule entirely defines life on our planet.

The illustrations throughout are a welcome visualisation of the more complex scientific principles, such as the bonds that form the shape of water. There is also some stunning imagery included, such as scenes from the Hon Khoi Salt Fields in Vietnam, or angular snowflakes under the microscope. All in all, this is a great addition to the library of any student or academic mind looking to sharpen their knowledge about the most abundant molecule on Earth.



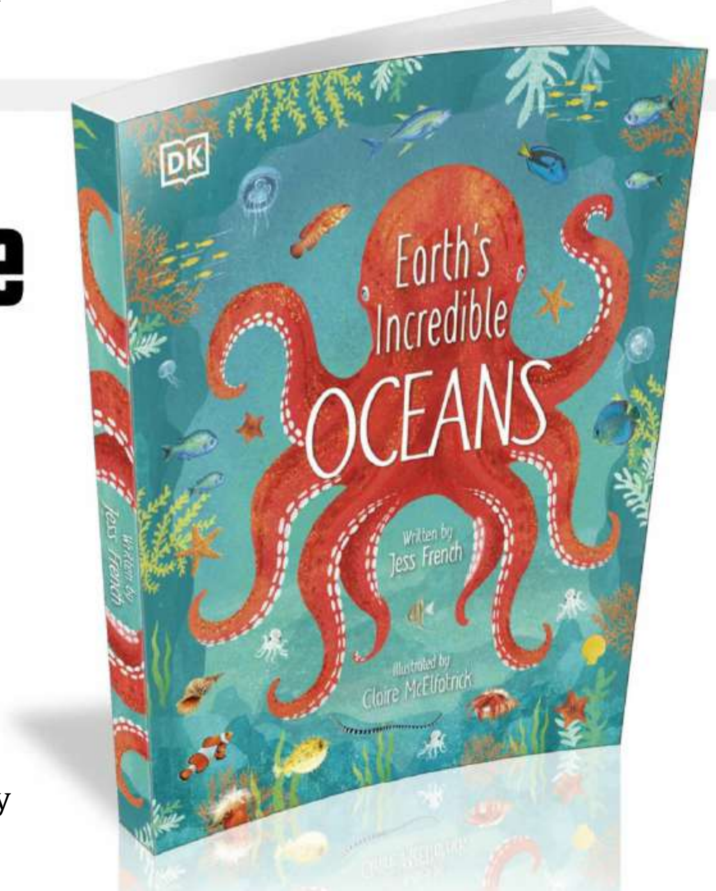
The story of water flows nicely from its origins

Earth's Incredible Oceans

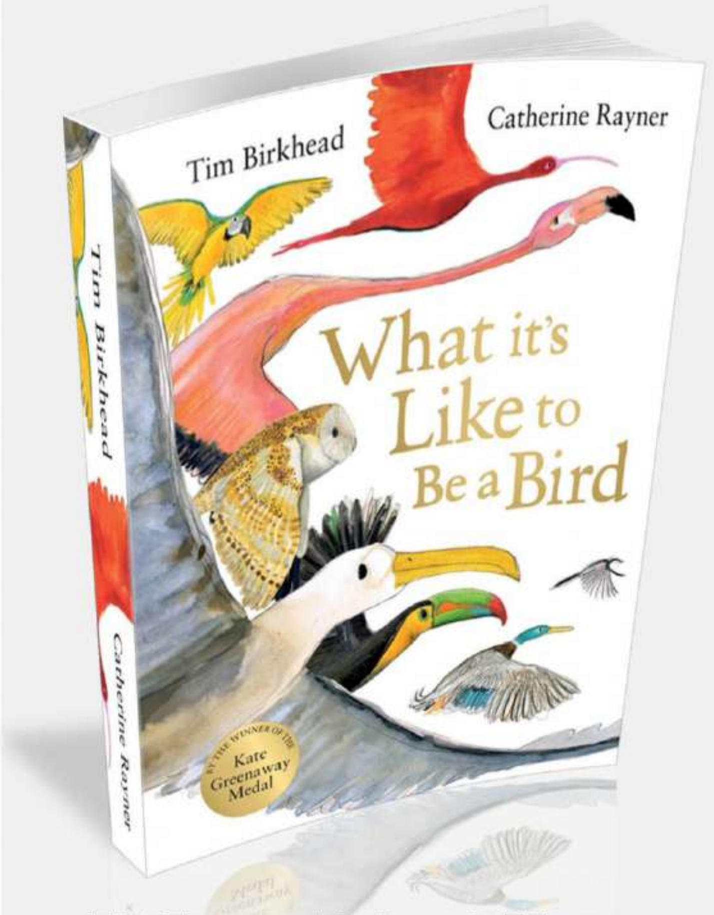
EXPLORE THESE DIVERSE DEPTHS

- Author: **Jess French**
- Publisher: **DK Publishing**
- Price: **£14.99 / $16.99**
- Release: **Out now**

This guide to our planet's oceans explains every important detail of underwater life. From the vast range of marine organisms and unique habitats to human exploration and the impact of pollution, this book is packed with fascinating facts and transporting illustrations. While the book is aimed at older children with an interest in ocean life, the information inside has the power to amaze both children and adults alike. The detailed food web will help readers understand the ocean hierarchy, while lifelike illustrations show how animals can swarm in unison and display expert camouflage to avoid becoming a meal.



Life isn't all about sole survival in the seas though, and one chapter explores the creatures who thrive by working together. The beautiful contrast in artwork complements the author's inclusive coverage of all areas of the ocean. With the explosion of colourful corals to the weird monster-like fish that lurk in the darkest depths, this book will provide readers with a much greater understanding of life beneath the blue blanket than what they usually observe from the shore.



What It's Like to be a Bird

PADDLE, SQUAWK AND SOAR THROUGH THE PAGES

- Author: **Tim Birkhead**
- Publisher: **Bloomsbury Children's Books**
- Price: **£12.99 (approx. $17.80)**
- Release: **19 August 2021**

Welcome to the world of birds. No matter where you are on the planet, you are likely to have watched a species of bird as it goes about its daily business. But have you ever wondered what it's truly like to live as one of these winged creatures? If so, this is the book for you. With every turn of the page, the author introduces you to a new species and guides you through their way of life. Immersing you in each habitat, you really get a feel for what it is like to live alongside our feathered friends.

Whether you're navigating the night with a robin's magnetic field detection or effortlessly soaring through the sky as the world's fastest bird, each encounter will teach you an impressive bird trait. This book not only informs on the habitat, movement and routine of each bird through the enthusiastic narrative, but adds personality to each one, allowing young readers to fully understand the reasons behind these animals' lifestyles.

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 When a space rock hits the ground, it's known as a _______?

○ Comet
○ Meteorite
○ Meteor
○ Asteroid

Q2 What part of the Earth does lava come from?

○ Inner core
○ Outer core
○ Mantle
○ Crust

Q3 Why is glacier and iceberg ice blue?

○ It's dyed
○ Blue algae live in it
○ It reflects the sea
○ It has no air bubbles

Q4 How tall is the world's tallest rocket, the Saturn V?

○ 30 metres
○ 111 metres
○ 360 metres
○ 1,030 metres

Q5 When was the mobile phone first patented?

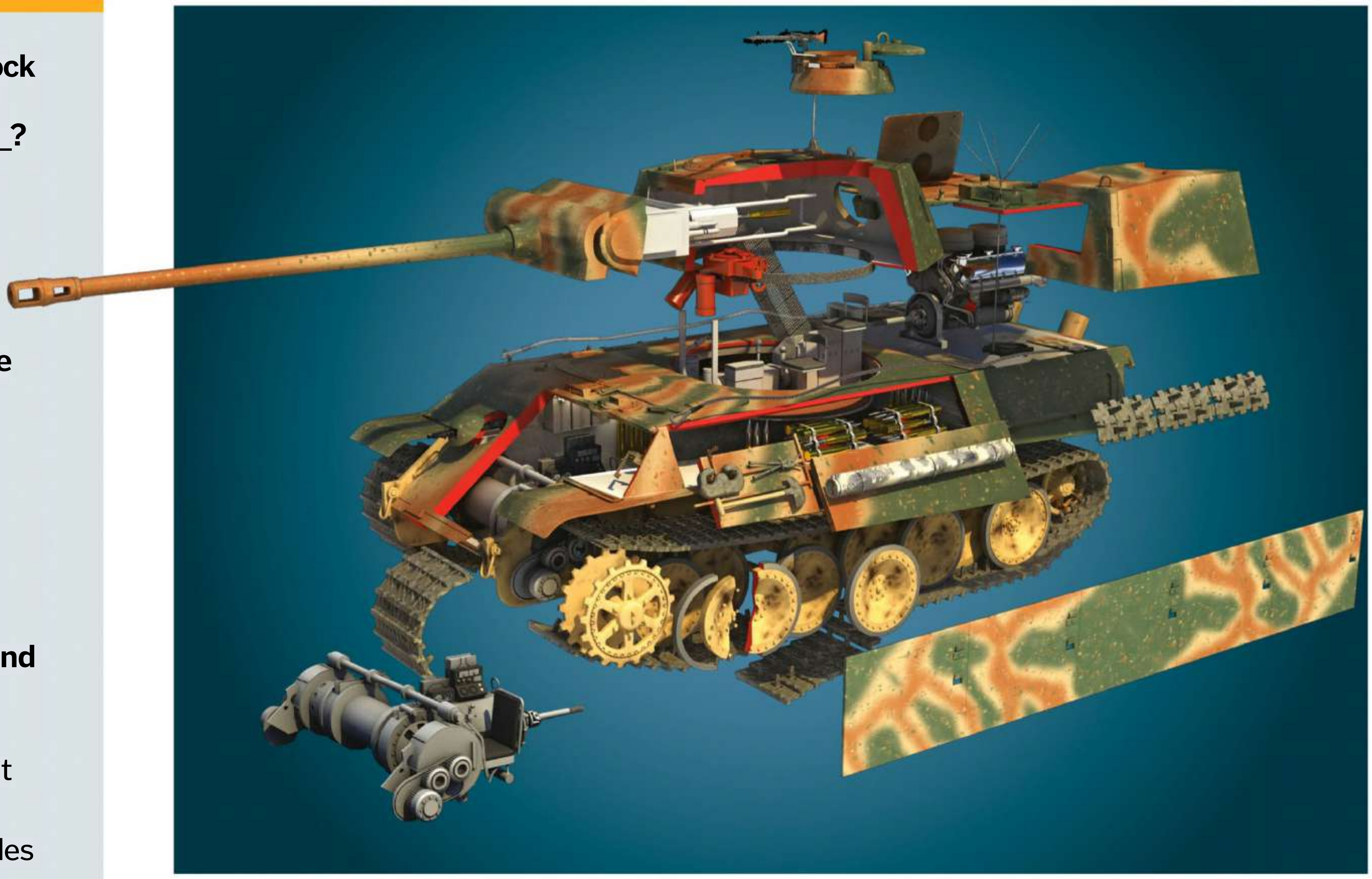
○ 1539
○ 1908
○ 1961
○ 1994

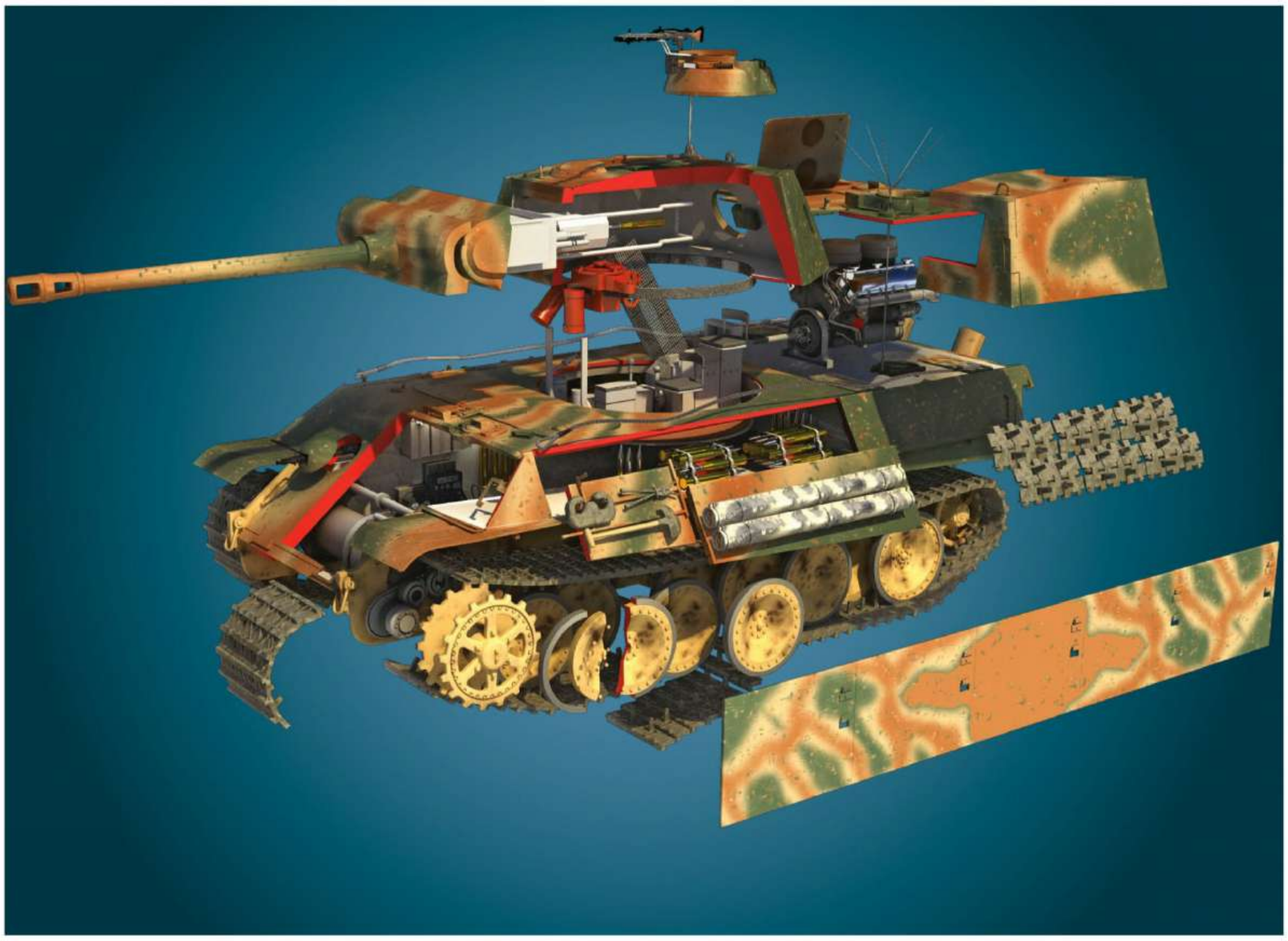
Q6 Approximately how many trees are in the Amazon Rainforest?

○ 510 million
○ 1.3 billion
○ 67 billion
○ 390 billion

Spot the difference

See if you can find all six changes between the images below





Sudoku

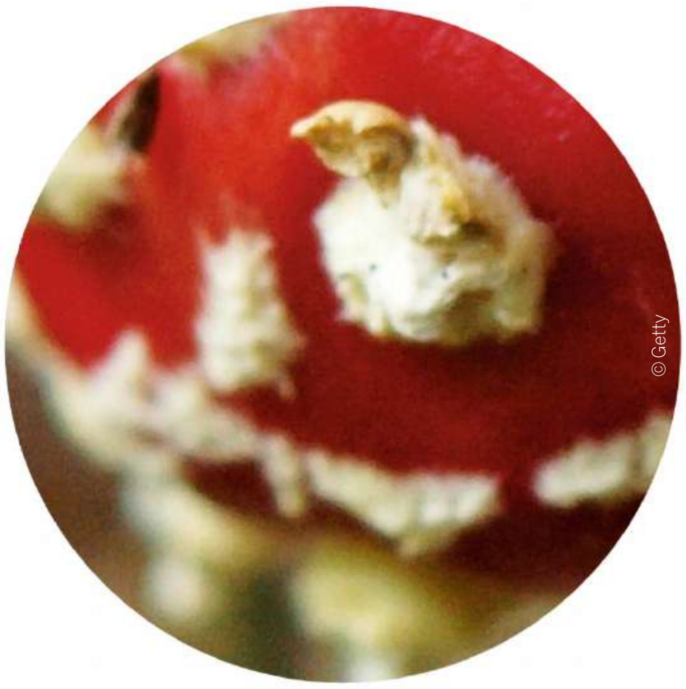
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

3			6			2		5
	9	5				4	1	
1		7	4	5	9	6	3	8
	3	2	7			1	5	4
8		6			5	3		
			2	9	3	7		6
	4	8	5	1			7	
		3		2	7		4	
	1		8			5	6	2

DIFFICULT

	8	1						
5	6			9		1	3	
					5	8		
8	1						9	5
			4					3
			3		8		2	
3		8					4	6
	2	4						
				6			5	



What is it?

Hint: A place for a small amphibian to sit…

A ....

P	A	A	R	J	E	T	S	R	A	M	I	G	O	S
S	E	D	I	N	O	S	A	U	R	E	B	I	D	A
O	E	A	R	U	Q	T	I	C	K	S	A	L	M	L
N	X	O	L	I	H	G	A	D	I	R	B	O	P	V
Q	T	A	N	E	A	Y	R	G	A	T	E	H	L	A
E	I	P	U	F	L	O	D	M	A	S	T	E	W	G
F	N	O	E	S	A	L	V	R	T	O	P	L	D	E
T	C	E	A	N	T	G	A	L	O	H	A	I	W	D
E	T	N	D	Y	O	R	K	I	T	G	H	U	Y	I
X	S	M	A	R	F	E	A	F	L	A	E	O	X	N
Y	P	G	H	O	R	O	D	L	B	O	X	N	A	O
E	T	U	L	A	V	S	I	S	I	T	O	M	L	N
U	T	E	K	I	T	C	H	E	N	A	L	G	A	P
D	O	H	G	S	A	L	E	X	T	I	J	A	G	I
Y	R	L	A	U	B	R	A	T	T	L	E	N	O	W

Wordsearch

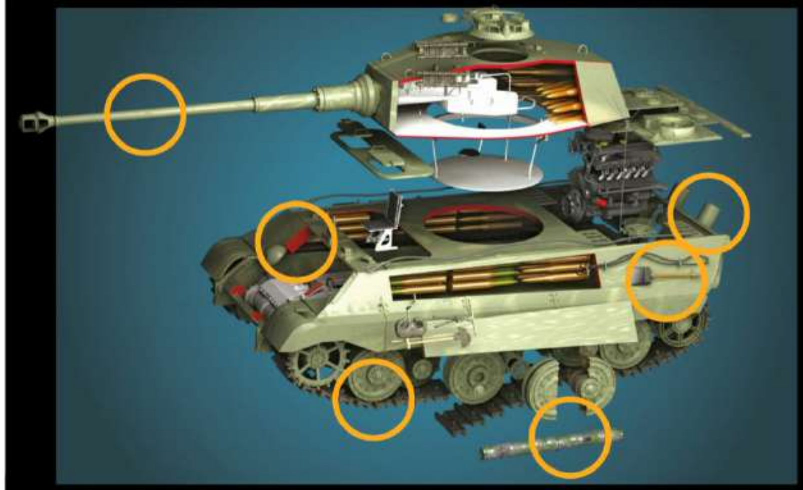
FIND THE FOLLOWING WORDS…

EXTINCT
KITCHEN
HYDROGEN
GHOST
ROT
SALVAGE
EAR
MARS
RATTLE
AUSTRALIA
GALAXY
DINOSAUR

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 Marsupial
Q2 Ancient ship burial
Q3 Calcium carbonate
Q4 Sound
Q5 Primordial soup
Q6 Helicopter

WHAT IS IT? …A FLEA

Get in touch
Send your ideas to...
How It Works magazine
howitworks@futurenet.com
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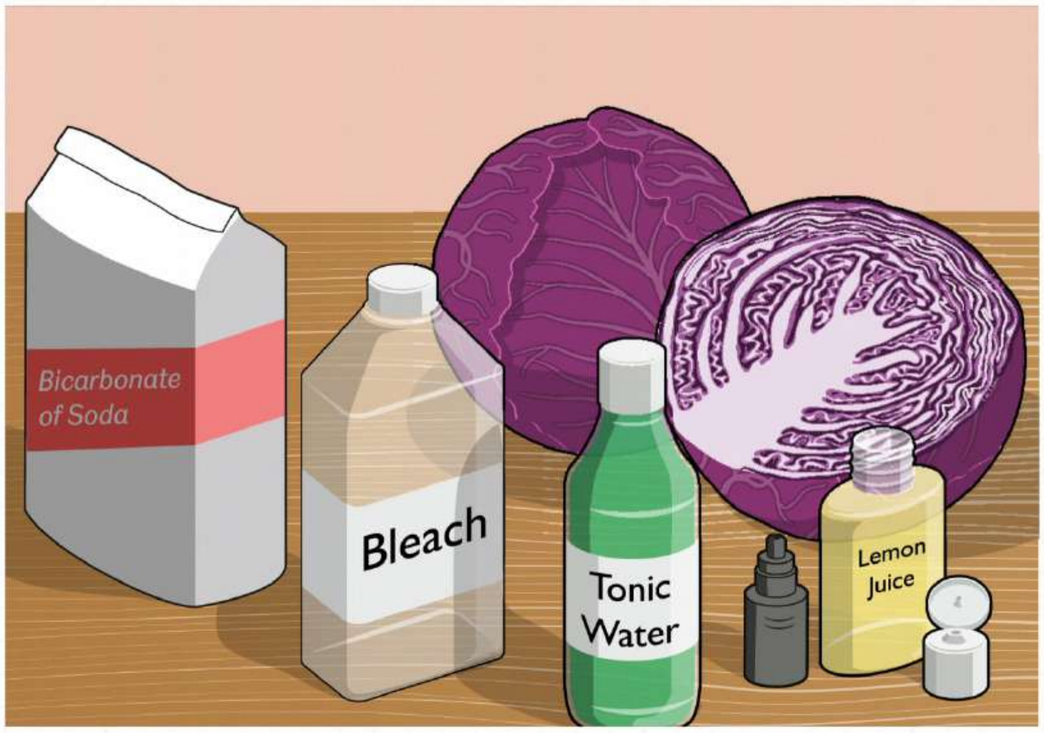
DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

Make a red cabbage acid test

Test the pH level of household products with this vegetable

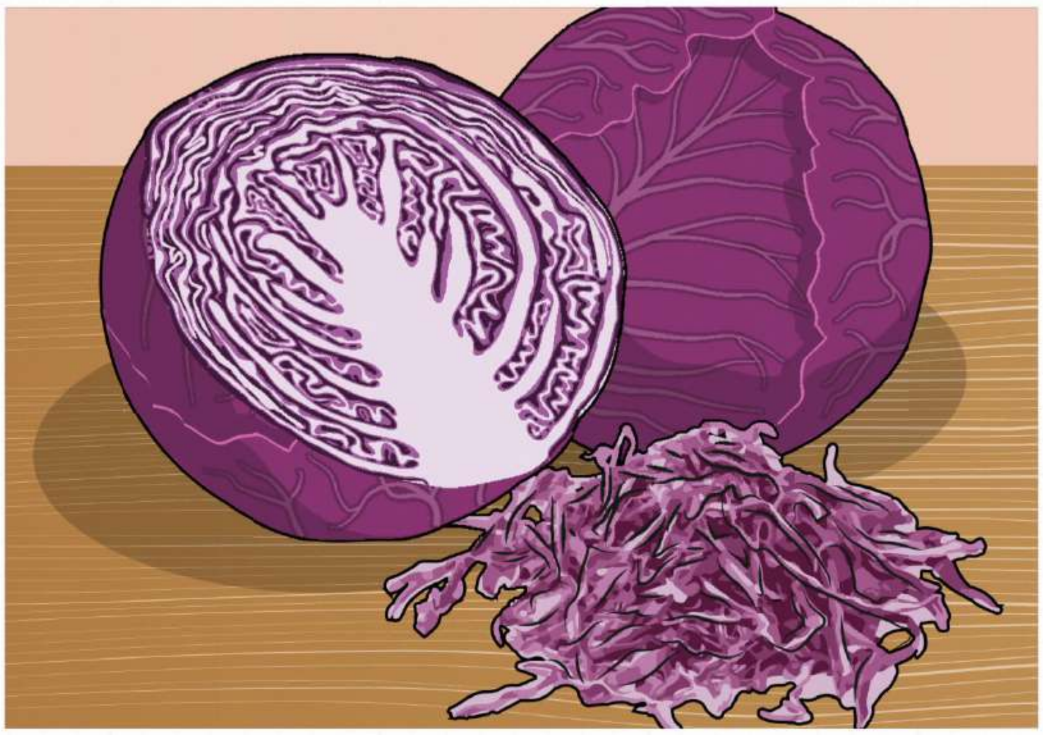
YOU WILL NEED:
- A red cabbage
- Boiling water

SOME THINGS TO TEST, INCLUDING:
- Lemon juice
- Bicarbonate of soda in water
- Spray cleaning product
- Bleach
- Rain water
- Tonic water



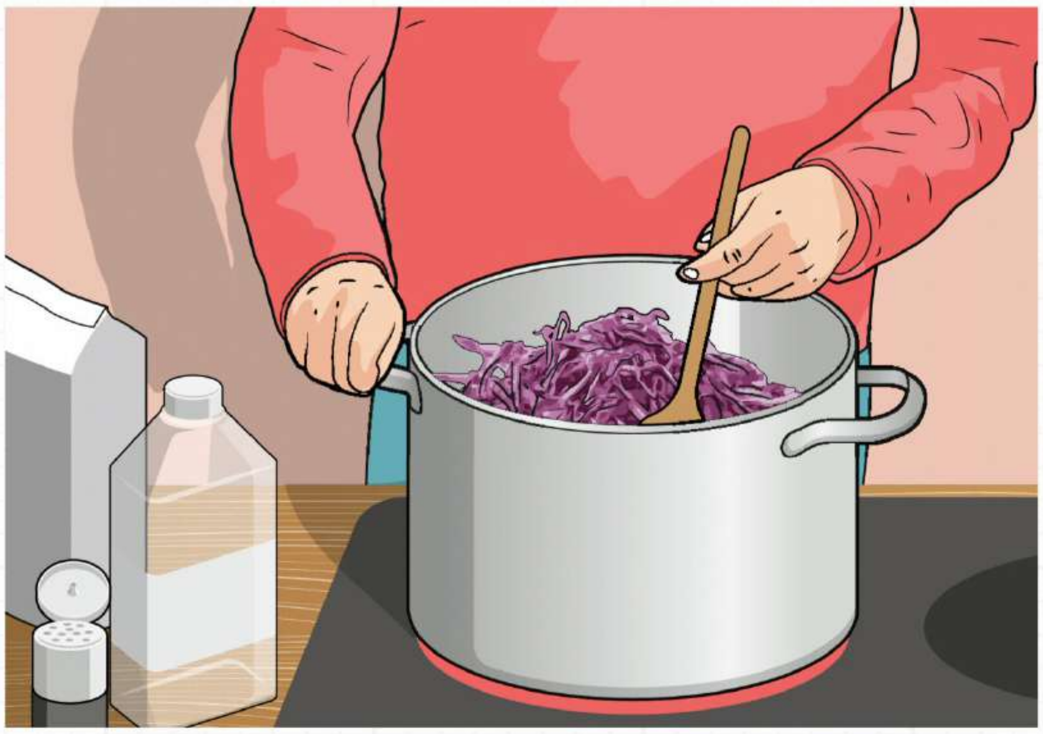
1 Gather your equipment

First, you will need one red cabbage and some boiling water. It's up to you which substances you test, but for the best range of alkalai to acid results, we recommend testing the various products and naturally-occuring substances in the list above.



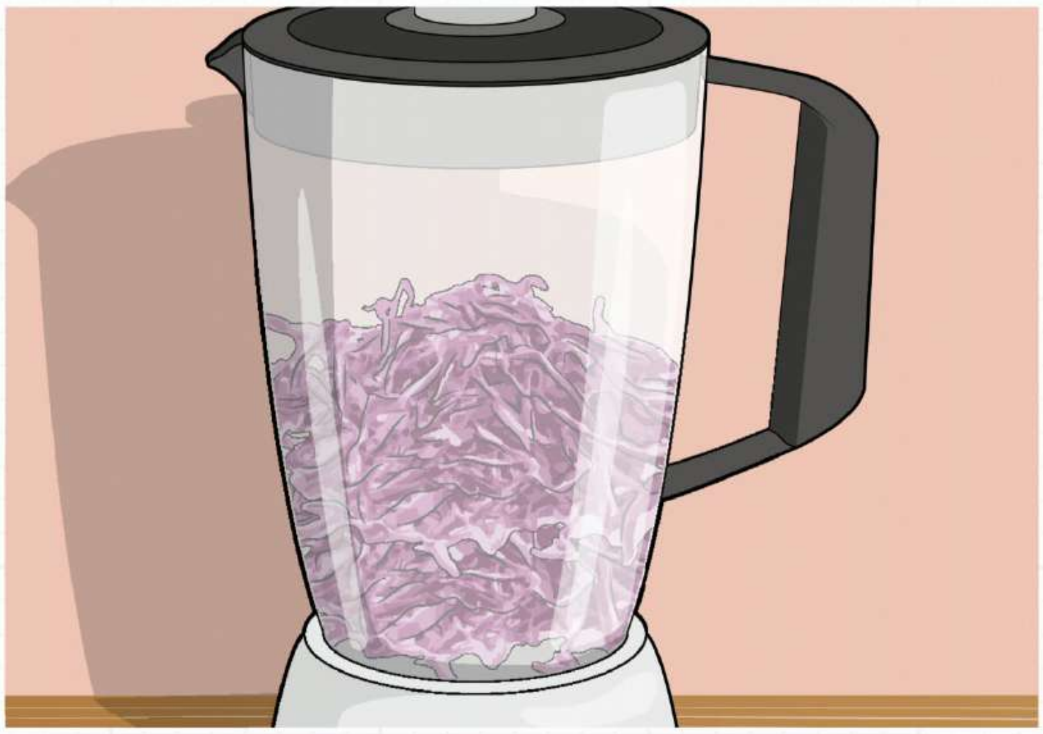
2 Cut the cabbage

Carefully cut your cabbage into thin pieces. You will need to estimate the volume depending on how many substances you would like to test, but half of the cabbage should provide you with around one litre of indicator. This will be plenty for your experiment.



3 Add boiling water

Place your cut-up cabbage pieces into a pan and cover them with boiling water. You will need to leave this to boil for about ten minutes. This process will soften the cabbage and begin to draw out some of the purple pigment.

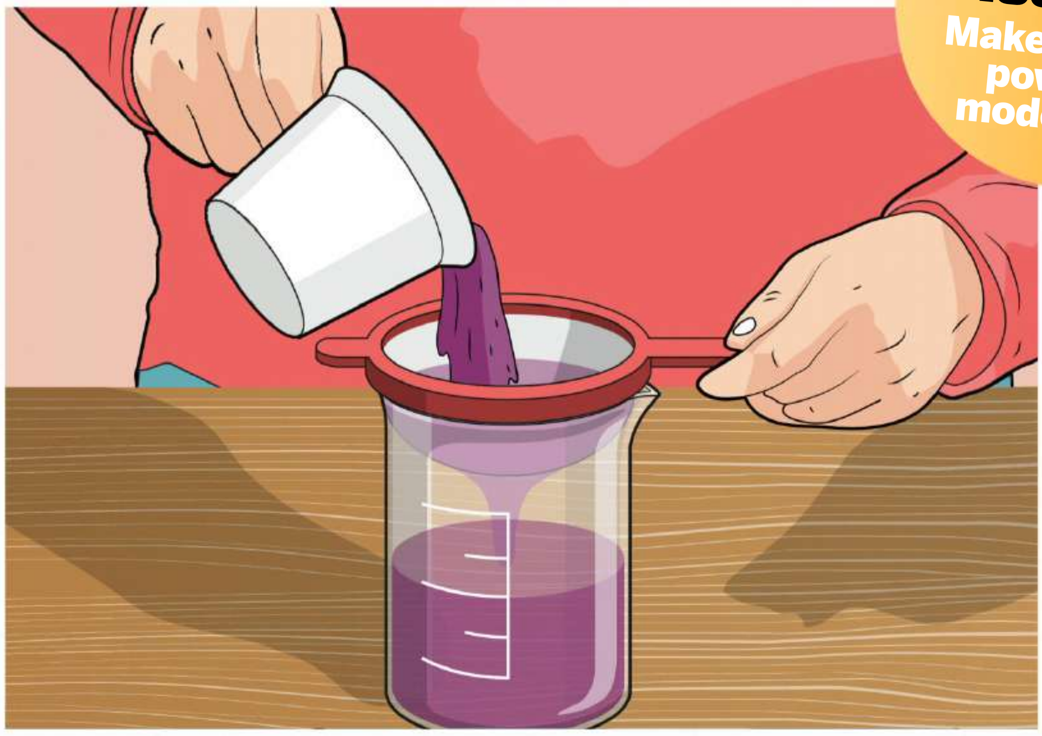


4 Blitz it

Leave the boiling water to cool for approximately 30 minutes, then transfer the water and cabbage into a blender. Blend the cabbage with the water to make the cabbage pieces much smaller. This will extract more pigment, but if you don't own a blender you can skip this step.

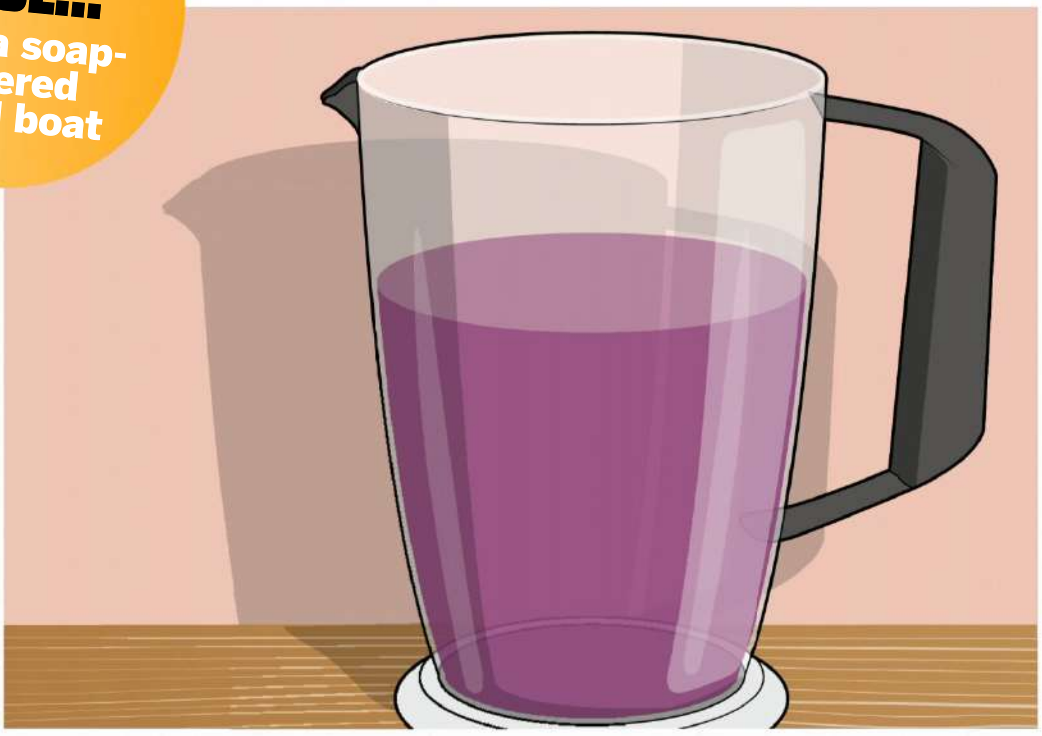
© Illustrations by Ed Crooks

NEXT ISSUE...
Make a soap-powered model boat



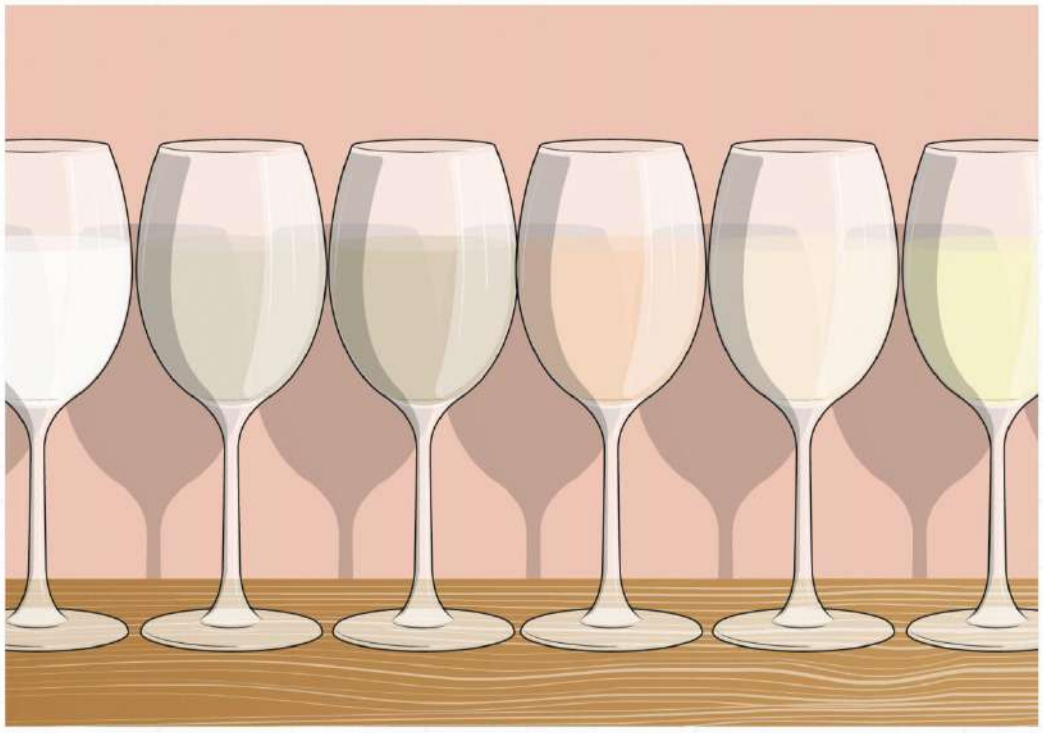
5 Strain the contents

Using a sieve, strain the colourful water into a large jug, leaving all the pieces of cabbage to collect in the wire mesh. After this stage, you will only need the liquid.



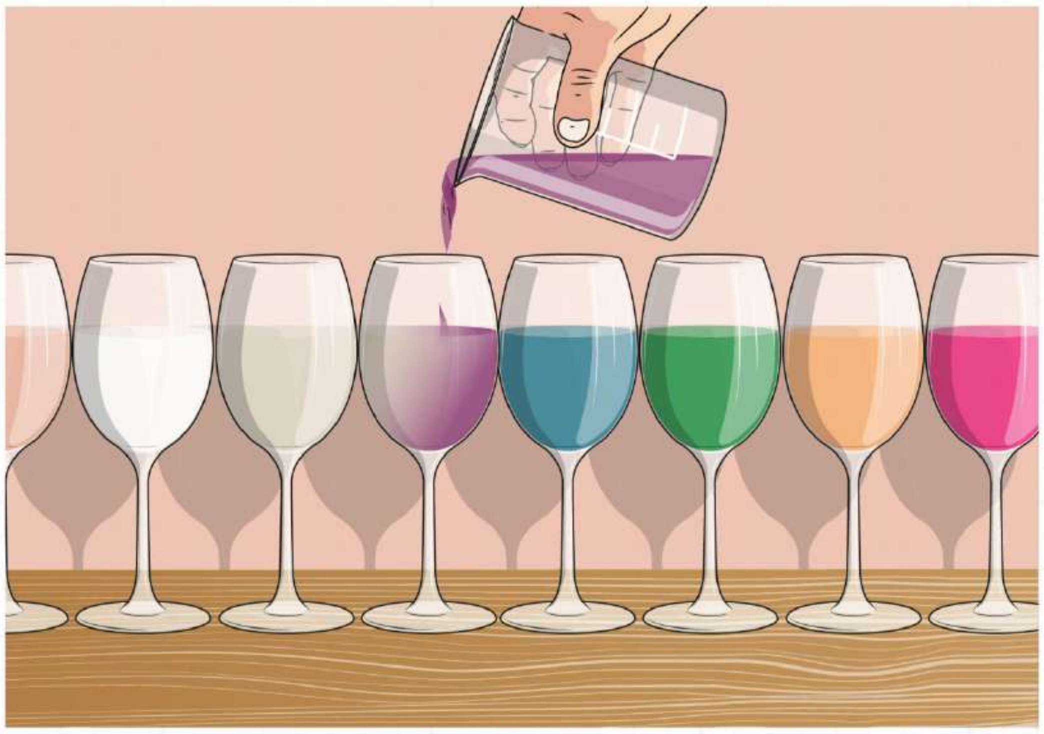
6 Collect the juice

The juice is full of anthocyanin, the pigment that gives the cabbage its colour. The colour of this pigment is highly dependent on the pH of the substance it is placed in, so it will work well as your pH indicator.



7 Assemble your substances

Gather the substances you wish to test. Pour an equal volume of each into separate glasses or cups. These cups need to be clear in order to observe the colour changes as they happen. It's a good idea to label the cups so you can remember their contents later on.

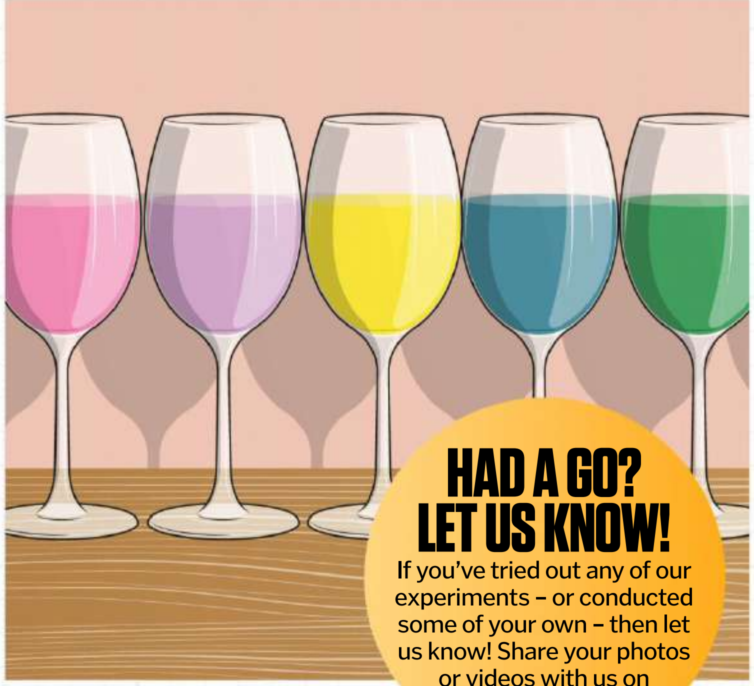


8 A splash of cabbage

Slowly pour about 30 millilitres of the cabbage juice into each glass. As you do so, watch how quickly each substance changes in colour. If the pigment becomes green or yellow, it has a high pH and is alkaline, while if it turns red or pink the substance is very acidic.

9 Analyse the rainbow

Line up the cups from alkaline to acidic. Any that have turned blue are neutral and should be placed in the middle of the scale. Keep the deepest red substance on the right. The general order should be yellow, green, blue, pink, red.



SUMMARY

The pH scale measures how acidic or alkaline a substance is. The more hydrogen ions there are in a solution, the more acidic it is. Acids will have a low number on the pH scale and will turn red or pink when the cabbage juice is added. The pH indicator in this experiment is the pigment anthocyanin. Naturally this pigment appears as a dark red or purple, and can be observed in red cabbage. This colour is seen because the anthocyanin molecules are absorbing the yellow, green and blue light. When placed in acidic solutions, anthocyanin is more stable. It absorbs more blue light and the intensity of the red hue increases. Meanwhile, when placed in high-alkaline solutions it loses stability and becomes green or yellow, as this light is no longer being absorbed by the pigment.

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HAD A GO? LET US KNOW!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag

howitworks@futurenet.com howitworksmag

A meteorite needs to survive its journey through space and the atmosphere before landing

© Getty

Made on Mars

Dear **HIW,**

Mars is in the news lately, and I frequently read about meteorites that arrived from Mars. How do we know this? There are a zillion possible places a meteorite could come from. We have no actual samples to compare these meteorites to, and I doubt they are stamped 'made on Mars', so how can we be so sure?

Ralph Varney

Today scientists have the tools and data to be able to determine where some meteorites originated. But this was not always possible. Thanks to spacecraft such as NASA's Viking landers, which touched down on Mars in the 1970s, we now know the chemical composition of Martian rock.

After this analysis of Mars' composition, it was discovered that many meteorites with unknown origins – which had been found before the Viking program – had the same chemicals inside. They also showed the same precise concentrations of these chemicals and contained the same trapped gases.

LETTER OF THE MONTH

DK
Earth's Incredible OCEANS

WIN!

EARTH'S INCREDIBLE OCEANS

Earth's Incredible Oceans explores the fascinating underwater world and the creatures that live there. Explore the seas and discover why it's important that we take care of them.

HIW in Zimbabwe

Dear **HIW,**

You may be aware that the situation in Zimbabwe is again terrible, with hyperinflation, huge unemployment and a daily struggle to buy food and stay alive for most people. People are not being paid, and so schools have closed and hospitals cannot function. I send American dollars via Western Union or small parcels with food supplies every few months to two families in Zimbabwe. One is in Victoria Falls and one is in Bulawayo. I also support a young Bulawayo man who moved to Johannesburg for work. I sponsored him some years ago through Plan International when he was a boy at school, and I visited his community in 2011. It would make some young people very happy to have your magazines to read, and I can see that your magazines are very educational.

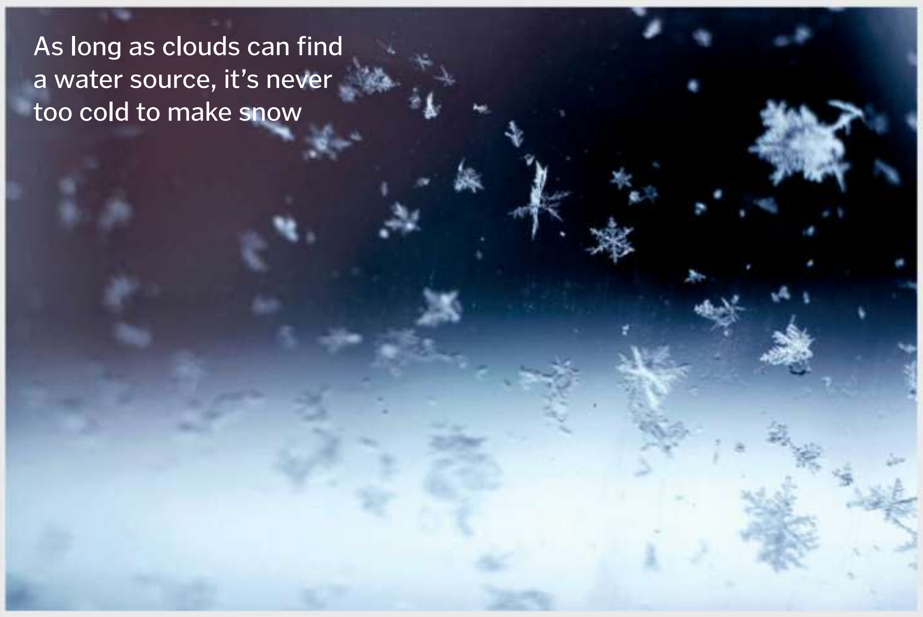
Cathy Dyer

We were delighted to receive this image from one of the families in Bulawayo, Zimbabwe, who have recently received some copies of How It Works from the team. In Bulawayo, schools are struggling to stay open because many teachers have left their positions or have moved to schools outside of the country. Receiving little or no pay, these teachers are forced to leave their jobs, and unqualified relief teachers have taken their place in some schools. Other schools have shut down indefinitely, denying children in these areas access to the education they deserve. Thank you Cathy for reaching out to us and arranging for these magazines to be sent to Zimbabwe. The work you are doing to support these families and provide them with educational resources is so worthwhile. We produce these magazines for readers of a wide age range worldwide, so thank you for making them accessible to more people. Hopefully this issue will make it to Bulawayo, too!

CAPE BOYZ
HOW IT WORKS
INTENSIVE CARE
GREAT PYRAMID MYSTERY

The boys in Bulawayo received two issues of **How It Works** magazine and will receive a third in two months

© Cathy Dyer



As long as clouds can find a water source, it's never too cold to make snow

© Getty

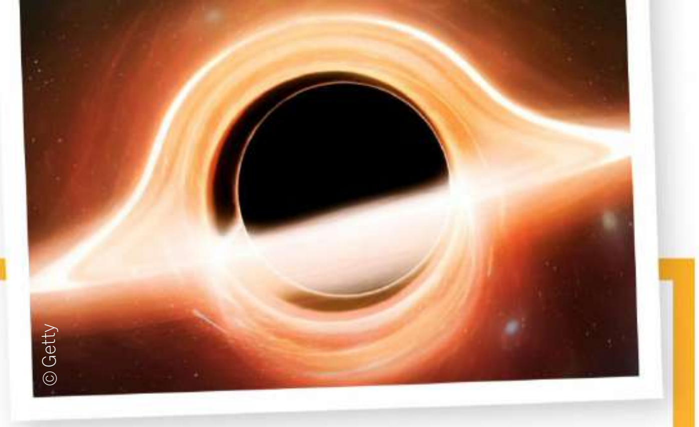
Snow's limit

Dear **HIW,**

When it gets colder than snow and hail, what comes from the clouds?

Sammy Glanfield

Hi Sammy, thanks for the great question. Interestingly, it can never really be too cold to snow, as snow can form at incredibly low temperatures. However, it is possible for the air to be too dry for snow to fall. Sometimes when temperatures are really low, the air becomes too dry. While this can be a result of the colder weather, it's the lack of humidity that is the cause, rather than the temperature itself. If there is little moisture in clouds during cold weather, they might begin to form snow crystals, but these flakes aren't big enough to reach the ground. Instead they evaporate before they reach us.


© Getty

Nothing can escape a black hole – not even light

Black hole theory

Dear **HIW,**

I have been fascinated by space and the universe's beginning and end and was wondering if you agree with my theory: the universe started by exploding outwards, and there is a theory that there could be a black hole at the centre of every galaxy, so the universe might end with one giant black hole sucking everything into it, then create a new universe by exploding because of the mass inside.

Duncan Craig

This is a fascinating theory, and one that has been explored by scientists before. Matter falls into black holes, causing them to grow in size, so it makes sense to believe that eventually everything surrounding them will be destroyed by them. However, it is predicted that less than 0.1 per cent of all matter in the universe will actually experience this outcome. Before more of the universe can be engulfed, a black hole decays. As it is constantly releasing radiation, in many billions of years a black hole will have reduced in mass, eventually vanishing.

Microscopic vision

Dear **HIW,**

Your magazines are amazing. What is the smallest thing a microscope can see?

Yifan Bao

There are two main types of microscope. The light microscope focuses visible light through its lenses to magnify an image. This allows people to see objects as small as 500 nanometres – 200 times smaller than the width of a human hair. Electron microscopes use beams of electrons instead. As electrons bounce off an object, a detector records the exact location of contact and turns these points into an outlined image. This enables scientists to see things with a length less than one nanometre. With this it's possible to view individual atoms within an image.

Microscopes were invented in the 16th century

© Getty

What's happening on...

social media?

This month on Instagram we asked you: If you could invent a new kitchen appliance, what would you want it to do?

@peter_Oconnor

Measure calories and nutritional content

@vanessa.___.chen

An appliance that can be attached to your fridge to regulate your diet and what you eat daily

@sammy.glanfield

Lay the table for you

@scimaxfacts

I would want it to be a machine that cleans the dishes for me

@jack_macneilly

Cook for me

@aesthetically_aj

I'd make a machine with extendable arms that goes through your shopping bags and organises their contents into the cupboards and fridge

NEXT ISSUE...

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FAST FACTS

Amazing trivia to blow your mind

62 MILES

THE NEW LHC PARTICLE ACCELERATOR WILL ENCIRCLE THE SWISS CITY OF GENEVA

21 BILLION GALLONS

THE JET FUEL THAT US AIRLINES USE ANNUALLY WOULD FILL OVER 30,000 OLYMPIC-SIZE SWIMMING POOLS

1777 to 1791

VERMONT WAS AN INDEPENDENT COUNTRY FOR 14 YEARS UNTIL IT JOINED THE UNITED STATES

3 BILLION YEARS OLD

LAVA TUBES ON THE MOON ARE NEARLY AS OLD AS EARTH

ONE KUWAITI DINAR

YOU CAN GET NEARLY £2.50 ($3.30) FOR A SINGLE UNIT OF THE WORLD'S STRONGEST CURRENCY

THE DEBRIS IN ORBIT AROUND EARTH WEIGHS OVER 9,000 TONNES

BUMBLEBEES NIBBLE ON LEAVES TO TRICK PLANTS INTO FLOWERING EARLIER

25,000 LIGHT YEARS

IN 1974, SCIENTISTS SENT A RADIO MESSAGE TO A DISTANT CLUSTER OF STARS

230 DECIBELS

SPERM WHALES CAN MAKE SOUNDS THAT ARE LOUDER THAN A ROCKET LAUNCH

50%

THE LONG-EARED JERBOA HAS EARS THAT ARE HALF THE LENGTH OF ITS BODY

SALMON FLESH IS PINK BECAUSE OF THE PINK SHELLFISH AND PLANKTON THEY EAT

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BATMAN VS JOKER
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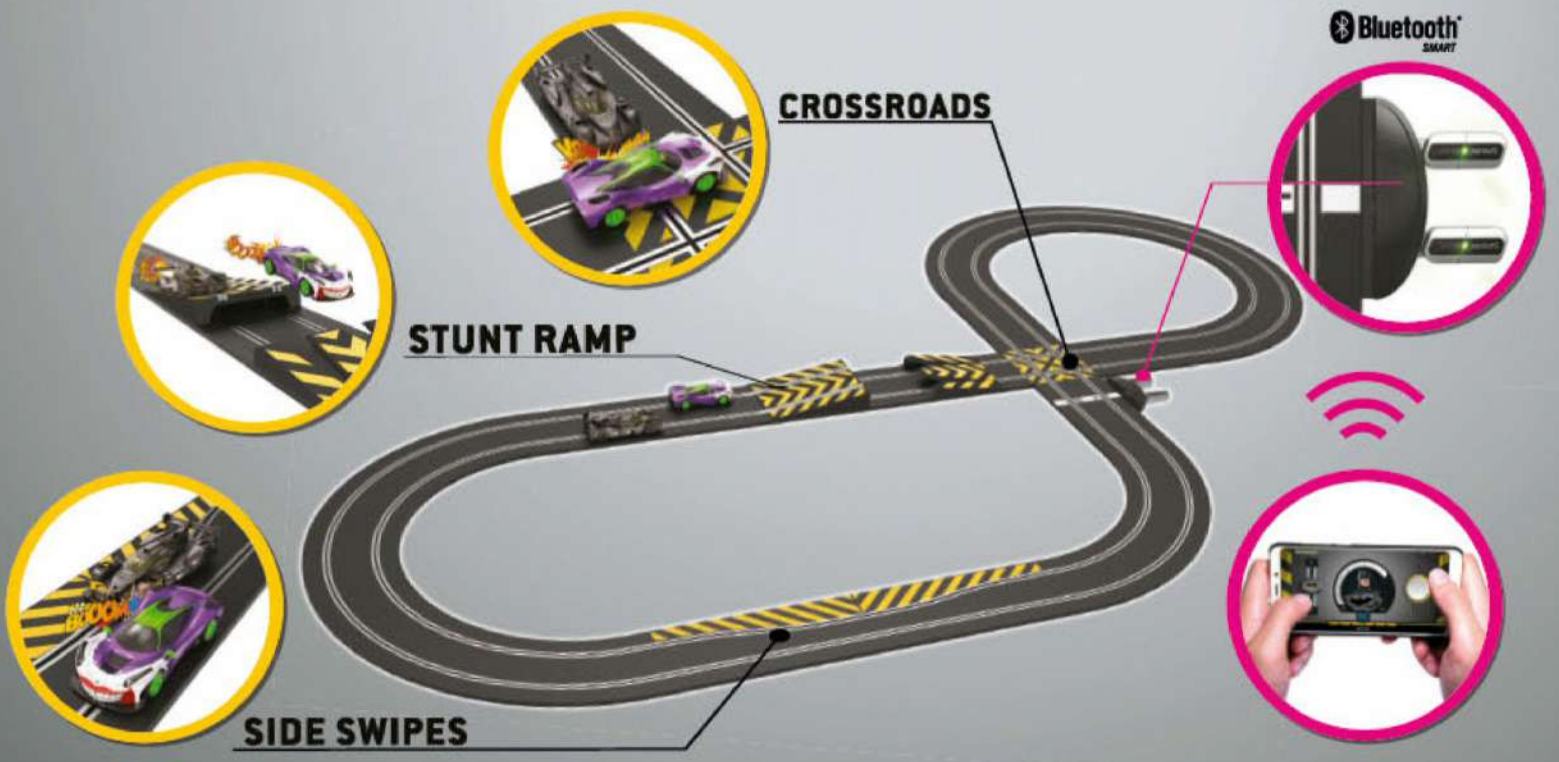
In this Batman vs Joker Spark Plug race set, you can race as one of Gotham's famous heroes or villains, including Batman, Joker, Harley Quinn, Penguin and more! Or become our own superhero or villain with the range of in-app filters, plus give yourself your own personal theme song with a soundtrack from your library.

The aim of the game is to stay on the track to keep all 10 of your lives – so choose your moments to boost or restrict speeds wisely, and use the action track pieces to knock your opponent off!



1 DOWN LOAD
2 PLUG
3 PICK CHARACTER
4 RACE

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